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ABSTRACT

The study was designed to investigate the effects on immediate acquisition, retention and transfer of two methods of presenting selected geometry concepts to sixth grade students. The effects of immediate acquisition and of transfer were measured immediately after presenting the lessons. The effects of retention were measured 1, 11, and 21 days after completion of the lessons. Two experiments were run. The first experiment considered the differential effects on short-and long-term retention of expository versus discovery methods of presenting the concepts. The second experiment investigated differential effects on immediate acquisition and transfer, of expository versus discovery methods of presenting the concepts. The results of these experiments showed that method of presentation did not differentially affect either immediate acquisition or transfer, but did differentially affect retention of the material in favor of th students who received lessons in the discovery mode. (Author/FL)

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Report from the Project on Situational Variables and Efficiency of Concept Learning

By Joseph A. Scott

Herbert J. Klausmeier, V. A. C. Henmon Professor of Educational Psychology
Chairman of the Examining Committee

Herbert J. Klausmeier and Robert E. Davidson, Principal Investigators

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

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The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practices.

This Technical Report is from the Situational Variables and Efficiency of Concept Learning Project in Program 1. General objectives of the Program are to generate new knowledge about concept learning and cognitive skills, to synthesize existing knowledge, and to develop educational materials suggested by the prior activities. Contributing to these Program objectives, the Concept Learning Project has the following five objectives: to identify the conditions that facilitate concept learning in the school setting and to describe their management; to develop and validate a schema for evaluating the student's level of concept understanding; to develop and validate a model of cognitive processes in concept learning; to generate knowledge concerning the semantic components of concept learning, and to identify conditions associated with motivation for school learning and to describe their management.

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ABSTRACT

This study was designed to investigate the effects on immediate acquisition, retention and transfer of presenting selected geometry concepts to sixth graders. Effects of immediate acquisition and of transfer were measured immediately after presenting the lessons. Effects of retention were measured 1, 11, and 21 days after completion of the lessons. Two experiments were run. The first experiment investigated the differential effects on short- and long-term retention of expository versus discovery methods of presenting the concepts. The second experiment investigated differential effects on immediate acquisition and transfer, of expository versus discovery methods of presenting the concepts.

Lessons were prepared using two presentation methods. Under the expository method, the name of the concept was given followed by positive and negative examples in which the relevant attribute was explicitly stated. Under the discovery method, a series of examples were given first. Ss were asked to describe the examples and to state how they were alike and how they were different. After all examples were presented, the name of the concept and its relevant attributes were given.

The subjects, who were sixth-grade children, studied the prepared lessons during a class period on four consecutive days (groups in the transfer experiment had lessons on five consecutive days). Ss were given a test of the concepts presented, either immediately after completion of the lessons for the immediate acquisition and transfer groups, or 1, 11 or 21 days afterwards for the retention group. No S was tested more than once.

The findings of the study were as follows:

1. Method of presentation differentially affected retention of the material. Test scores of Ss who received lessons in the expository mode decreased over time, while the scores of Ss who received lessons in the discovery mode increased over time. This interaction between method of presentation and retention interval was significant.

2. Method of presentation did not differentially affect transfer.

3. Method of presentation did not differentially affect immediate acquisition.

Chapter I

INTRODUCTION

History of the Problem

Is it better to define a concept for a child and then illustrate with a sequence of examples, or to allow the child himself to induce or deduce the concept from a series of examples? Psychologists have examined this question for several decades without reaching a definitive conclusion. Some psychologists (e.g.,Ausubel, 1967) state that it is better to tell the older child the principle first and then illustrate with examples. Others (e.g.,Bruner, 1961) hold that there are more advantages to allowing the child to discover the concepts and principles himself. The formulation of the question in the terms used above is of recent origin, but the ancestry of the problem is long, and its resolution has been sought by men of letters and science for over two thousand years.

The "history" of this problem can be traced back, as can many other problems in modern psychology, to a similar controversy in the writings of Plato. In The Republic, after he has told the parable of the cave, Socrates concludes, "but then, if I am right, certain professors of education must be wrong when they say that they can put knowledge into the soul which was not there before, like sight into blind eyes" (Plato, 1963). Socrates was arguing for the existence of

innate ideas as opposed to knowledge put into the soul, which was apparently being advocated by the "certain professors of education." These professors, it would appear from history's perspective, were to carry the day, however. Instruction via lecture and admonition appears to have been unopposed in ancient Rome, and throughout the Middle Ages. But the issue was revived with the publication of Emile. Rousseau stated it this way:

> Direct the attention of your pupil to the phenomena of nature, and you will soon awaken his curiosity; but to keep that curiosity alive you must be in no haste to satisfy it. Put questions to him adapted to his capacity, and leave him to resolve them. Let him take nothing on trust from his preceptor, but on his own comprehension and conviction: he should not learn, but invent the sciences [italics mine]. (Boyd, 1956)

Herbert Spencer was more vehement still:

> Nearly every subject dealt with is arranged in abnormal order: definitions, and rules, and principles being put first, instead of being disclosed, as they are in the order of nature, through the study of cases. And then pervading the whole, is the vicious system of rote learning, a system of sacrificing the spirit to the letter. See the results. What with perceptions unnaturally dulled by early thwarting, and a coerced attention to books--what with the mental confusion produced by teaching subjects before they can be understood, and in each of them giving generalizations before the facts of which these are generalizations--what with making the pupil a mere passive recipient of other's ideas, and not in the least leading him to be an active inquirer or self-instructor--and what with taxing the faculties to excess; there are very few minds that become as efficient as they might be. (Spencer, 1860, pp. 47-48)

In the first half of this century the controversy raged again between traditional and progressive education as characterized by Dewey (1938). He stated that "the history of educational theory is

marked by opposition between the idea that education is development from within and that it is formation from without." He portrays the controversy between traditional and progressive education as an example of the debate in action.

> To imposition from above is opposed expression and cultivation of individuality; to external discipline is opposed free activity; to learning from text and teachers, learning through experience; to acquisition of isolated skills and techniques by drill, is opposed acquisition of them as means of attaining ends which make direct vital appeal; . . . etc. (P. 19)

But even to the present time, the issue does not appear to be either resolved or dead.

It is well to note that discovery is being advocated by all of the foregoing because it is the more "natural", or more "proper" way of learning and not because it might produce better retention, or because it might be more efficient. Such contentions are not, therefore, operationally definable nor empirically testable, and the results of the studies reported in the remainder of this dissertation cannot be introduced as support for one position or the other. Later researchers have tended to concentrate their attention on such factors as retention, where empirical research can be brought to bear on the question.

Inconclusiveness of the Debate and Research

Psychologists, too, have joined in the debate and introduced empirical laboratory-type research towards its resolution. Chapter 3 reviews a series of experiments, starting in 1932 and continuing to the present, which have addressed themselves to this problem. This research is generally reported under the rubric of discovery learning.

The most complete discussion of this literature and the controversy that surrounds it is best reported in Learning by Discovery: A Critical Appraisal (Shulman & Keislar, 1966). Despite this history of interest, debate, and research, there is little evidence of a definitive nature which can be brought to bear on the question posed at the beginning of this dissertation. Summarizing the findings of the Conference of Learning by Discovery, Lloyd Morrisett (1966) concluded that "research on the topic of discovery . . . is relatively impoverished . . . first in the range of variables that have been considered . . and second in the subject matters that have been studied" (p. 179). Wittrock (1966) prefaced his review of the research with the warning that the current state of research on discovery is very disappointing and precludes any important conclusions about teaching and learning" (p. 45). He states that research in the field suffers from problems with the conceptual issues, methodology, semantic inconsistencies, and lack of generalizability.

This dearth of significant findings in the research to date has not, however, lessened the conviction of many educators (e.g., Davis, 1966) and psychologists (e.g., Bruner, 1961) that the issue is an important one for education and that further research should be expended toward its resolution. The equivocal nature of the findings taken in toto, probably emanates from several sources. Critical examination of the literature indicates that the controversy simultaneously revolves around epistemological, ethical, psychological, pedagogical and theoretical questions. Among the points of view noted above, it can be seen that Socrates represented a purely epistemological point of view, Dewey a pedogogical approach

from an epistemological base, Rousseau a pedagogical position from an ethical base, etc. It is also entirely probable that the polarity in points of view between Ausubel and Bruner noted in the first paragraph arises less from the difference in their psychological approach than from their differing definitions of the word "better" as it is used in the question. This situation points to the necessity of an increasingly rigorous definition of both independent and dependent variables used in the research as well as more explicitly stated questions or hypotheses. This happily, has been the direction researchers have moved in recent years. One of the most important considerations is assessment of the effect on learning and retention of various methods of presenting stimulus materials to students in classroom situations. The present study addresses itself to this question.

This point of view avoids the epistemological "red-herring" introduced with the word "discovery". The conclusion of the Conference on Learning by Discovery was that even such a basic consideration as the definition of discovery was not agreed on by the participants. Howard Kendler (1966, p. 1976) in his concluding remarks at the conference pointed to the confusion and lack of communication involved in the use of the word "discovery" and called for its abandonment. Abandonment of the word "discovery," however, is highly unlikely, and furthermore will not solve any problems. A more acceptable approach in this author's opinion is: (1) to formulate a more acceptable definition of the concept discovery; and (2) to accept the position that pedagogical questions such as that posed at the beginning of this chapter can be answered without reference to the epistemological phenomenon or the psychological process called "discovery."

Background of the Present Study

The question "Is it better to define a concept for a child and then illustrate with a sequence of examples, or to allow the child himself to induce or deduce the concepts from a series of examples?" was posed at the beginning of this dissertation. As noted earlier, this question can be answered in a straightforward manner, once "better" has been operationally defined, without any reference to "discovery learning". Nevertheless, the question itself evolved directly from a series of studies on discovery learning, and the parameters and questions of the present study can be traced back to that series of studies. Wittrock (1966) makes a useful distinction between studies of discovery as an intervening variable and studies of discovery as an independent variable. The studies of discovery as an intervening variable are more directly related to psychological theory, to an examination of the psychological processes involved in discovery. These studies yielded few definitive results. Later studies have concentrated on identifying functional relationships between independent and dependent variables and have less commitment to the concept of discovery per se. It is primarily from this last group of studies that the present experiment evolved. A second useful way of looking at the research on discovery learning is to group the studies into those performed in psychological laboratories and those performed in classrooms with curricular materials.

Studies by Kersh (1958, 1962) and Gagné and Brown (1961) are characterized by Wittrock as investigations of discovery as an intervening variable, but can be classified as laboratory studies.

Kersh (1958) found a No-Help group superior to a Direct Learning Group. In a later study, Kersh (1962) found that Rote Learning and Guided Discovery groups were superior to a Directed Learning group. It should be noted that Rote Learning was equivalent to No-Help and, therefore, the most extreme discovery group. Gagné and Brown (1961) found that a Guided Discovery group performed best while a Rule and Example group was worst.

Among the studies of discovery as an intervening variable using curricular materials in the classroom are those by Swenson (1949) and Anderson (1949). Swenson found no differences among the groups on measures of retention but found that results of transfer tests generally favored the Generalization (Discovery) group. Anderson, like Swenson, worked with sixth graders and found an interaction between treatment and ability level, as measured by the Minneapolis School Ability Test. Performance was best for low ability students under the Drill method, and best for the high ability students under the Discovery method. The discrepant results of these studies, and the impossibility of comparing either their dependent or independent variables prohibit firm conclusions regarding discovery learning.

A second group of studies are those characterized by Wittrock as studies of independent variables. Craig (1953, 1956), Kittel (1957), Haslerud and Myers (1958), and Wittrock (1963) typify this kind of study. Craig (1953) varied the amount of guidance given to four groups. Results indicated that the amount of guidance was directly and positively related to retention and transfer. Later, Craig

(1956) compared two groups, a No-Help and a Directed Group. On an immediate transfer test and on a transfer test 31 days later the Directed group was superior. On a test for transfer administered 3 and 17 days after the test, no differences were found. Kittel (1957) found that an Intermediate Direction group was superior on both retention and transfer tests, to a Minimum Direction group and a Maximum Direction group. Haslerud and Myers (1958) found a Directed group superior on a test of immediate acquisition but inferior on a test of retention. Wittrock (1963) found that an intermediate amount of direction produced greater retention and transfer than minimum and maximum direction.

The following two studies typify discovery studied as an independent variable in classrooms, with curricular materials. Twelker (1967) examined the effects of expository and discovery learning and their interaction with teachers' use of praise and guidance. No clear cut findings favoring either treatment emerged. Worthen (1968) found that the Expository treatment was superior on a test of initial learning while the discovery group was superior on a retention test and on a test of transfer of heuristics.

The studies just cited illustrate the problems involved in making statements about the relative effectiveness of discovery learning. One study found no differences between expository and discovery learning, another found expository learning superior on a test of initial acquisition but discovery learning superior on a retention test. The other studies evidence the superiority of no, some, and much guidance. The source of this confusion is no doubt due in

part to the fact that although the task in the various studies is usually clearly stated, the characteristics and dimensions of the materials themselves are not specified. Since number and sequence of examples, ratio of positive and negative instances, and amount and kind of feedback have been shown to be powerful variables affecting learning of concepts, if such descriptions are omitted, labels such as "intermediate directions" are virtually meaningless.

Worthen's study introduced more rigor into the definitions of expository and discovery learning, defining them in terms of the sequence of stimulus presentation. Worthen's study was, however, of long duration and under the direction of various teachers. This raises questions about the amount of guidance that may have been given by teachers, and effects of reinforcement from interaction with teachers, aside from the effectiveness of the written material. It is not clear from Worthen's study, what the effect of the written material alone might be. Worthen's study also suffers from the lack of definition of stiumlus materials mentioned above. Finally, Worthen tested each S on five different dependent variables administered consecutively. The effect of earlier tests c ie later tests was not ascertained. In examining the variables he chose, Worthen had to necessarily forego examination of a number of other variables. By locking at teacher effects, he could not assess the effect of the printed material alone.

The present study examined the effects of two methods of presenting material in printed form only. Materials were constructed

such that number and sequence of examples, ratio of positive and negative instances, and amount and kind of feedback as well as the principle to be discovered could be specified for each concept introduced. Finally, in this experiment only two tests were administered to each S, one embedded in the lesson material, and one after completion of the lessons, so that spurious effects would be eliminated. Worthen's use of "expository" and "discovery" to describe the manner of presenting the stimulus material will be used in the study.

The intent of this dissertation is to make a contribution at three levels. (a) The experiments assessed the effects of expository and discovery methods of presenting selected geometry concepts on retention and transfer. (b) Materials were prepared along specifiable dimensions. A complete description of the material utilized will be given for each presentation method. (c) A description of the concept discovery is presented which may be useful in comparing findings of previous studies and in designing future studies.

Purpose of the Experiment

The experiment was designed to investigate the effects on retention and transfer of two methods of presenting selected geometry concepts to sixth graders. The effects on retention were measured at three points: 1 day after completion of the lessons, 11 days after the completion of the lesson, and 21 days after the completion of the lessons. The effect on transfer was measured immediately after completion of the last lesson. Assessment of the effect of method of presentation on immediate acquisition of the selected concepts was also measured immediately after completion of the lessons.

The following specific questions were asked:

1. Is there a difference in the level of retention of the selected quadrilateral concepts at 1 day, 11 days, and 21 days for students who are presented the concepts in an expository mode and students who are presented the concepts in a discovery mode?

2. Does presenting a set of concepts on triangles in the expository or discovery mode differentially affect the subsequent learning of the selected quadrilateral concepts presented in either the expository or discovery mode?

3. Does the level of immediate acquisition of the selected quardilateral concepts differ for students who are presented the concepts in an expository or discovery mode?

Experiment 1 will address itself to question 1. Experiment 2 will address itself to questions 2 and 3.

Method

A pilot study was run to answer logistical questions regarding administration of the lessons and test, pinpoint problems in the procedure, and test for effects of the lessons which had been prepared. The methodology of the main study was based on the results of the pilot study.

Subjects. Ss were 256 sixth-grade students from six schools in Stevens Point, Wisconsin. Eleven classes which had no prior training in the concepts being presented were used.

Task. A series of lessons were presented to the Ss, one lesson

per day. The series consisted of either four or five lessons, depending on the treatment group (see Tables 4 and 5 for complete listing). The content and structure of the lessons is described in the section on materials. Immediately following the last lesson for those Ss in the transfer group and 1 day, 11, or 21 days later for the other groups, a test to determine level of retention of the concepts was administered.

Procedure. Ss were randomly divided within schools into 15 groups. All Ss except control groups were first presented two introductory lessons. Experiment 1, which addressed itself to question 1 above contained nine groups. Groups 1, 2, and 3 were presented lessons on quadrilaterals in the discovery mode; Group 1 was tested 1 day after presentation of the last lesson, Group 2 was tested 11 days afterwards, and Group 3, 21 days afterwards. Groups 4, 5, and 6 were presented lessons on quadrilaterals in the expository mode, Group 4 being tested 1 day later; Group 5, 11 days later; and Group 6, 21 days afterwards. Groups 7, 8, and 9, and the control groups, received placebo lessons on unrelated materials and were tested at the same times as the 1 day, 11 day, and 21 day groups above.

Experiment 2 addressed itself to questions 2 and 3 above, and contained six groups. Groups 10 and 11 were presented a lesson on triangles in the discovery mode; Group 10 was then presented lessons on quadrilaterals in the discovery mode, while Group 11 was presented lessons on quadrilaterals in the expository mode. Groups 12 and 13 were presented a lesson on triangles in the expository mode; Group 12 then received lessons on quadrilaterals in the discovery mode and Group 13 received lessons on quadrilaterals in the expository mode.

Groups 14 and 15 did not receive lessons on triangles; Group 14 received lessons on quadrilaterals in the discovery mode and Group 15 received lessons on quadrilaterals in the expository mode. Groups 10 through 15 were tested immediately on completion of the last lesson. Tables 4 and 5 show the Groups, and lesson and test sequence.

Significance of the Study

Since the independent variables under investigation proved to have significant effects on retention or transfer or both, this may have possible implications for the manner in which printed materials, such as textbooks and other reading materials, are prepared for sixth-grade children. The structuring of the materials used in this study is such that it will allow for systematic variation in subsequent experiments to arrive at optimal conditions of presenting such printed materials. The same structuring should provide a vehicle for constructing lessons in other curricular material so that it can be determined if the effects obtained are generalizable to other subject matter. Finally, the dissertation will essay a comprehensive description and definition of discovery which might be used as a common denominator in comparing the studies in the literature and in designing future studies.

Chapter 2

EPISTEMOLOGICAL NOTES ON DISCOVERY

Although "discovery" and "discovery learning" are used frequently in the literature in educational psychology and teaching practice, the usage is inconsistent and the concept appears to be very poorly understood. The purpose of the present chapter is to increase understanding of what is implied by the use of the word "discovery." The chapter is not, however, intended as a comprehensive treatise on the subject. Rather it will describe the epistemological phenomenon called discovery as opposed to the psychological process of discovery, and will seek to clarify the problem of what is discovered.

Review of the Problem

When one speaks of "discovery", what exactly is one talking about? If one even briefly reviews the psychological literature it would appear that one might mean one or all of a variety of events, processes or phenomena. The word is used in quite different ways by different psychologists and the reader has the unhappy job of deciding whether each usage is a subset of some larger meaning or whether the psychologists are applying the same words to different and independent phenomena or processes. The decision

must be made, however, if one is to judge the scope, generalizability and applicability of the research results cited. The following samples will illustrate the variation in the use of the word "discovery."

Robert Glaser (1966) stated that discovery sequences are characterized by two properties: inductive sequences and trial and error learning. Gagné (1966) said that discovery involves inferring (a) an internal process of search and (b) an internal process of selection. He then suggested that discovery so described could occur at each of the seven levels in his hierarchy of learning. Kagan (1966) equated the "inferential approach" with the discovery approach, and stated that the discovery method required the child to infer a major principle "without excessive guidance from an external source." (italics mine). In addition to this he described discovery as teasing out a simplifying rule. Bruner's (1961) definition of discovery is so broad as to "include all forms of obtaining knowledge for oneself by the use of one's own mind." A little farther on in the same article, is a more restrictive definition, i.e. that "discovery is in its essence a matter of rearranging or transforming evidence in such a way that one is enabled to go beyond the evidence so reassembled to additional new insights." This resynthesis, he added, is not always dependent on new information. Shulman (1970) in a recent article, represents discovery a la Gagné as going from the simple to the

complex and discovery a la Bruner as going from the complex to the simple. Shulman also places the roots of Bruner's model in the Socratic method. Worthen (1968) describes the discovery method of teaching as one where "verbalization of each concept or generalization is delayed until the end of the instructional sequence by which the concept or generalization is to be taught." The students are first given a series of examples of the concept.

Examination of these definitions and descriptions suggests that some psychologists are defining discovery as an epistemological event while others are defining it as a psychological process. The difference between these characterizations might be summarily described as the difference between stating what is acquired and when it can be said to have been acquired, and stating how it is acquired. This distinction will be elaborated in the remainder of the chapter. Although the definitions in the preceding paragraph are not entirely precise it appears that Gagné in his definition is describing a psychological process; Kagan is describing an epistemological event; Glaser's definition incorporates both, and Bruner's could be either depending on how he defines "transformed." In Gagné's definition, a process or series of behaviors(though they may be internal responses) is being postulated and examined, while in Kagan's a set of criterial results is taken as evidence that some event called discovery has occurred; in the first instance the process discovering is being examined; in the second instance discovering is assumed to have, or is defined as having, occurred. The differences will now

be examined in more detail.

Epistemological Description of Discovery

Description of Discovery. The following criteria are postulated for specifying whether or not an event called discovery has occurred:

It will be accepted that S has discovered the proposition P, that is to say that proposition P is true, if

1. at time t_1 S does not know that P is true.

2. at time t_2 S does know that P is true.

3. if in the interim $t_1 - t_2$ S has not been told that P is true.

The following clarifications are necessary to render this description more precise. (1) A proposition is used here in the same sense as Beardsleys' usage (Beardsley & Beardsley, 1965) that is "what it is that a person knows when he knows that something....a proposition is (a statement) that can be true or false. When you know that cats are carnivorous, you know the proposition that cats are carnivorous; you know the proposition 'Cats are carnivorous' is true." Proposition, then, as used here is taken to include concepts, principles, rules, generalizations etc. (2) Told as used in this description refers to any manner or method in which P might be communicated to S by another person. (3) It will be accepted that S knows P to be true, if:

a. P is true.

b. S accepts the correctness of P.

c. S can present evidence that P is true, upon demand.

Evidence shall consist of either a valid deductive argument or a strong inductive argument, or alternately a prediction and demonstration that P is true. Behavioral scientists would probably accept a broader operational definition for "c". Piaget's research would suggest that children prior to the stage of formal operations may not be able to present evidence that P is true in the sense required above. Rather than exclude children in the preoperational period and the period of concrete operation, this author will accept that such a child knows P if he responds at better than chance level on a test designed to suggest that the child knows that P. The criteria specified above for asserting that S knows, are prima facie non-commutative i.e. failure to meet these criteria does not imply that S does not know, nor does it imply that S has not discovered P (cf. Strike, 1970).

It should be reasserted at this time that the above description of discovery, views discovery as an epistemological event. That is to say this description establishes criteria by which, in the case of any given proposition, it can be determined on a yes/no basis whether or not that proposition was discovered. The objection has been raised that this description allows for a situation such as the following: S1 is told each attribute of a concept, but the concept itself is not verbalized. S2 is not told any of the attributes but the concept is verbalized for him. Using the criteria above it would have to be concluded that S1 discovered the concent, or a proposition, P_x, regarding the concept, assuming that S1 knows P_x,

while S2 did not. The contention is, however, that S2 discovered more than S1 and that, therefore, the criteria are misleading. The following points will, perhaps, clarify the situation. Using the criteria above it must be accepted that S1 discovered P_x, S2 did not. What S2 discovered (given that the evidence is produced) were other propositions P_i, P_j, P_k regarding attributes of the concept. S1 did not discover P_i, P_j, P_k. It should be clear from this that the criteria above can be applied to each sub-concept, dimension, and attribute of the concept under consideration, *ad infinitum*. Thus, it is possible to use these criteria to state whether or not a concept was discovered, and in addition, how much of all the prior information leading to the concept, was discovered.

Induction and Deduction. In the psychological literature on discovery, one finds many statements regarding induction and deduction. The most prevalent point of view coincides fairly well with Glaser's statement (1966) that discovery is characterized by the inductive process. Glaser describes induction as a procedure of giving exemplars of a more general case which permits the student to induce the general proposition involved. This, too, appears to be typical of the interpretation of induction as used by psychologists writing in the literature on discovery. Rather than pointing to the inadequacies of these definitions, the intent here is to present a more complete description of deduction and induction, as these words are used by philosophers, and to suggest that psychologists begin to use them in the same way. Sk[illegible] (1966) calls the

view of induction as going from specific to general, and deduction as going from general to specific, "n nsense, but nevertheless a widespread misconception." He then provides a description of each, which is in large part the basis for the following remarks. Beardsley's (1966) statement on the differences between induction and deduction is more succinct and will serve as a point of departure. He says that the difference is "a difference in what we can hope to accomplish by way of proving something." In a deductive argument the rules of inference are clear. Simply stated they insist that if the premises of an argument are accepted, and if the argument is valid according to the prescribed rules, then it is necessary that the conclusion be accepted. In inductive arguments the attempt is to put the conclusion beyond reasonable doubt by offering sufficiently strong arguments in its favor. There is, therefore, no stipulation that the argument proceed from specific to general or vice versa. Skyrms has in fact shown that it is possible to construct both deductive and inductive arguments which go from general statements to general statements, specific statements to specific statements, specific statements to general statements, and general statements to specific statements. (Skyrms 1966, pp. 13-14)

Since the direction in which the argument proceeds is irrelevant to the kind of argument being put forth, the difference lies in the rule by which the conclusion of the argument is accepted. If the conclusion derives necessarily from the premises, then it is a deductive argument. (Mathematicians call it a proof.) If the propositions is not deriveable from the premises, but can be

shown to have greater or lesser probability on the basis of the evidence presented, then it is an inductive argument but not a proof. The following example may illustrate and clarify this to some extent. The following three statements constitute a valid deductive argument, that is to say that if the premises (1 & 2) are accepted the conclusion is incontrovertible.

1. All human beings feel pain.
2. John is a human being.

---

3. John feels pain.

Statement 1, however, can be arrived at in two ways, deductively as the conclusion of a set of premises such as:

1. All mammals feel pain.
2. All human beings are mammals.

---

3. All human beings feel pain

or inductively, through the following kind of argument: I am human; I feel pain. I know many fellow humans. All assure me that they feel pain. I believe them. Reports of many doctors and psychologists, historians and writers of literature show that the human being reported on indicate feeling or having felt pain. I believe at least this aspect of these reports, and therefore conclude that all human beings feel pain. The inductive argument contains none of the incontrovertible features of the deductive argument. Even at its strongest it is a probabalistic statement.

What is Discovered?

Discovery may be defined in the manner outlined above as a phenomenon presumed to have occurred when certain events are observed. It may also be described as a set of ongoing processes; what it is that S is doing when he is discovering. Examination and description of these processes will be easier if there is first some attention given to what it is that is discovered.

The criteria for determining whether or not discovery had occurred, cited earlier, all concerned themselves with S discovering a proposition. This is not to hold that only propositions can be discovered but rather to say that whatever is discovered must be put in propositional form if it is to be put forth and evaluated. It is legitimate to ask what type of events might be discovered and put in propositional form. Three groups of events or phenomena are postulated to include most if not all of what is discoverable.

a. Fortuitous events.

b. Experimental laws, or knowledge acquired as the result of exploration, and the accumulation of new facts and experiences.

c. Theories, or knowledge acquired as a result of the restructuring of current knowledge.

Fortuitous events can be subdivided into unplanned happenings and serendipity. The former refers to events like Columbus's running into America on his way to India. The latter refers to events such as the discovery of penicillin or vulcanized rubber, where a search was in progress for something but what was found was not exactly what was being looked for. Since by definition it is almost

impossible to include such events in a curriculum or a program of experimentation, no further attention will be given to this group of events.

Ernest Nagel (1961, Chapter 5) makes a distinction between experimental laws and theories. This distinction will be used as a base from which to describe type of events or phenomena (a) which are discoverable, (b) which can be put in propositional form and (c) which will also be meaningful in educational experimentation and curriculum planning. Nagel sees the aim of scientific thought as understanding observable things by discovering some systematic order in them. He describes the final test for the laws that serve as instruments of explanation and prediction as their concordance with such observations. These are what he calls experimental laws. Theories are a "set of assumptions about some phenomena which employs terms which ostensibly designate nothing observable and which assumptions cannot be confirmed by experiments or observations of the things to which the terms refer." Toulmin (1953 p. 53) describes the difference more elegantly. He speaks of looking for regularities of given forms versus seeking the forms of given regularities.

What this author then takes to be discoverable in the case of experimental laws is a pattern or rule common to all observations, or a set of attributes held in common by all exemplars. Experimental laws refer not only to the scientific endeavor but also to all concepts and principles. One presumably has acquired a concept when one can identify a pattern, a rule or attribute common

to all examples of the concept. When one discovers a concept, then one presumably discovers that common attribute or rule. This author includes this behavior under what Nagel designates as the supra-ordinate class of experimental laws. Two stages are involved in the discovery of experimental laws: first, critical observation of instances examined; then, determination of common patterns.

Theories on the other hand involve postulated patterns first, then observation of events to determine if they coincide with the rules predicted by the theory. If concordance is observed then an explanatory theory can be said to be discovered. Thus, Nagel observes, that "though experimental laws may suggest a theory and a theory may explain experimental laws, the laws can survive the demise of the theory since they rest on an observational base. Thus, the meaning of laws can be formulated independently of the theories, but theoretical notions cannot be understood apart from the particular theory that implicitly defines them. Discovering theories, then, would include much hypothesis testing and problem solving behavior, as well as the type of behavior defined as "creative" in the psychological literature. Two stages are involved in the discovery of theories: first, hypothesizing a set of relationships or series of consequences; second, testing the hypothesis for concordance between the theory and observation.

Briefly stated, then, what can be discovered apart from fortuitous events is either a rule or pattern which describes observed regularities among instances, or concordance or nonconcordance between a postulated pattern and subsequent observations.

The Process of Discovery

The foregoing abbreviated discussion of what is discovered suggests a sequence of processes which could lead to S's discovery of an experimental law or a theory. In the case of an experimental law, four processes are involved: (i) exploration and observation, (ii) identification of rules or attributes or both as a consequence of these observations, (iii) discriminating patterns or regularities, and (iv) stating the observed regularities. If the fourth step produces a statement regarding a pattern, rule, or set of common attributes, then this author will hold that discovery of an experimental law has occurred. In the case of theories, five processes are involved: (i) hypothesizing on the part of S, (ii) exploration and observation, (iii) identification of rules, attributes, or patterns among what is observed (iv) comparison of observations with hypotheses, and (v) stating the concordance or nonconcordance between hypothesis and observations. These processes do not differ greatly from Gagne's (1966) processes of internal search and internal selection. They go beyond Gagné, however, in providing for external search as well as internal search and for external identification in addition to internal selection, and in providing for an external statement of S's findings.

Discovery and Guided Discovery

The criteria specified for determining whether discovery has occurred do not exclude methods generally listed as guided discovery. For the purposes of this paper "guided" will be taken to indicate the presence of a structure or of clues, in greater or lesser amount.

This stiucture shou1' be specifiable both in terms of the number of rules or attributes told or to be discovered, as well as number and sequences of exemplars, etc., and should increase the probability of S discovering that the proposition P is true.

Discovery and Expository Learning

Discovery learning will be taken to be what is learned when some P is discovered. Expository learning will be taken to be non-discovery learning. The criteria for expository learning will be that:

1. at time t_1 S does not know that P is true.
2. at time t_2 S does know that P is true.
3. in the intermin $t_1 - t_2$ S has been told P is true.

All of the other specifications described earlier will hold. It should be obvious from this that there exists the possibility of many kinds of expository learning, depending on the degree to which P is structured and the number of rules, attributes, rules etc., so that the nature of the total learning experience can be specified.

It is obvious from this discussion that expository learning and discovery learning are such broad concepts, that comparison of the two without a virtually exhaustive description of the stimulus situation is meaningless.

Chapter 3

RELATED RESEARCH

Research on discovery learning has been periodically reported in educational and psychological journals during the past forty years. The result of this research is equivocal, and more work of the kind suggested in previous chapters is needed before definitive conclusions can be drawn. Nevertheless, it may be useful to review a representative group of the studies performed over the past four decades to compare the parameters of the studies and their findings. It is possible to divide these experiments into three groups on the basis of the independent variables being studied: experiments which compared discovery and non-discovery methods of presenting stimulus materials; experiements which examined the effects of varying degrees of guidance; and studies of the effects of verbalization. Most of the studies reviewed here (the exceptions will be noted in context) measured either retention transfer, or both. In addition to noting the independent and dependent variables, and the results of the studies, the types of Ss and tasks employed the studies will also be compared.

Discovery vs. Non-Discovery

In one of the earliest experiments of this kind, McConnell

(1934) used second grade Ss in a seven-month study. The stimulus materials were 100 addition and subtraction facts. The methods were: Authoritative, in which Ss were told to memorize the facts, and Discovery, in which Ss were told to discover the generalization involved in the task. The results showed the Authoritative method to be best on speeded retention, but discovery to be superior on transfer tests.

Thiele's (1938) design and methodology was similar to McConnell's. Thiele's task also consisted in learning 100 addition facts and the subjects were again second graders.

Treatments were Generalization, in which Ss were told to look for a generalization, and Drill, in which facts were presented without any attempt by E to relate them to each other. Training time was seven weeks. Performance of the generalization group was superior on all measures of retention and transfer.

Katona (1940) used a somewhat different task. Ss, graduate students in psychology, were assigned to one of three groups. Ss in the Memorization Group were told the correct sequence of cards required to perform a trick; Ss in the Understanding Group were told the way in which the solution could be derived; Ss in the Control Group received no training. Training time was four minutes. Results showed Ss in the Memorization Group to be superior on a test of immediate retention, while the Understanding Group was superior on a test of transfer to similar problems. Both groups were superior to the control group. The results were replicated in a second experiment with one additional result. On a retest four weeks after training,

the Understanding Group was superior both on memory and transfer.

Swenson's (1949) Ss were second grade students. The task was learning of 100 addition facts and the duration of training was 16½ weeks, with 25 minute lessons each day. Treatments were: Generalization Method, encouraging the students to build up interrelationships; Drill Method, presenting facts in miscellaneous order; and Drill-Plus Method duplicating standard teaching procedures. This included manipulation of objects in addition to drill on facts. Results showed little difference among groups on initial learning, but the Generalization Group was higher on both retention and transfer.

Anderson (1949) used fourth grade students and applied his treatments to the material taught in the regular math curriculum from November through May. Treatments were Drill and Meaning methods, essentially those described in the Swenson Study. On standardized arithmetic tests he found no differences among group as a function of method of teaching. This would presumably be a test of retention. A test of mathematical thinking which could be considered a transfer test was also given. Ss of high ability but inferior achievement, who had received the Meaning method of training, performed best on this test.

Worthen (1964) reported the following series of comparative studies in mathematics, which juxtaposed Traditional with Discovery methods of teaching. Sobel (1954) used high IQ ninth-grade students. The task consisted of a series of algebra problems. The Discovery method proved superior. Fullerton's (1955) task was the learning of multiplication facts. Treatments were Inductive vs. Deductive methods of presenting the material. The Inductive method proved superior on

measures of initial learning, retention and transfer. Ss were third graders. Pincus (1956) compared a Rote-Memorization method with an Understanding method but found no significant differences between the methods.

The general, though by no means universal, finding of these studies appears to be that discovery methods of instruction are not superior to rote or drill methods when the criterion is immediate learning or short-term retention, but becomes superior when the criterion is either long-term retention or transfer. The findings of these studies do not appear to be related to task or age of Ss.

Amount of Guidance

By far the largest group of studies reported have examined this independent variable. Ewert and Lambert (1932) varied amount of guidance using four treatments. Method 1 gave S the objectives of the problems and rules of procedure. Method 2 also gave Ss objectives and rules and, in addition, asked Ss to find one general principle applicable to all problems. Method 3 gave Ss objectives, rules, and general principles. Method 4 added a demonstration to the procedures of Method 3. Results showed greater guidance to be most effective. The methods, in the order of increasing superiority, were 1, 2, 4, 3. The task had required the movement of discs among three circles. The dependent variables in this study were time to criterion and number of moves.

Stacey (1949) used sixth-grade Ss to compare the effectiveness of five methods: two of which could be characterized as discovery methods and three as authoritative methods. Amount of guidance varied among the five methods. The task consisted of elimination of one word that

"did not belong" from a set of five words. Although the conclusions drawn favored discovery methods and minimum guidance, few of the findings reached a .05 level of significance.

Craig (1953) used a task similar to Stacey's. Ss were males, recent college graduates who were being commissioned as second lieutenants in the U.S. Air Force. Four levels of guidance were used: zero clues (Group Z); grouping of stimulus material to maximize discovery of relationships (Group G); information that the stimulus material was grouped according to some principle (Group GX); and a fourth treatment where Ss, in addition to the receiving the information given to Group GX, were told the grouping principle (Group GXP). Results showed that number of errors to solution of the problem was inversely related to amount of guidance. Amount of transfer increased in direct relationship to the amount of guidance. In a second study Craig (1956) used two treatment groups with college Ss. The task was similar to that used in the previous study. The treatments consisted of either no clues (Independent Group) or a short general statement of the relationship among the items (Directed Group). The directed group was superior on a test of initial learning and on a retention test administered 31 days later, but not on a retention test administered 3 and 17 days after completion of the task. No differences were found between the groups on a transfer test.

Kittel (1957) also utilized a task similar to Stacey and Craig's, but with sixth-grade students. Three levels of guidance were labeled Minimum, Intermediate and Maximum. The Intermediate Direction group used in this study appears to be equivalent to the GXP (Maximum direction)

group in the Craig (1953) study and the Directed Group in the Craig (1956) study. Results showed the Intermediate direction group superior on all measures of retention and transfer.

Corman (1957) also varied amount of guidance using the Katona matchstick task (Katona, 1940). Twelfth-grade students were Ss in this study. The experiment produced results showing a complex set of interactions among mental ability, kind of information given, and dependent measures.

Haslerud and Myers (1957) used a code deciphering and enciphering task. Ss were college students. Treatments were No Directions regarding the code and specific directions. The No Directions group was found to be superior on a transfer task. The validity of the analysis has, however, been disputed many times, e.g. Wittrock (1966), Cronbach (1966).

Wittrock (1963) also examined the effects of varying amounts of guidance on a discovery task. Using college Ss and a code deciphering task, he formed four groups, varying in degree of guidance: Rule given, Answer given (RngAg); Rule given, Answer not given (RgAng); Rule not given, Answer given (RngAg); and Rule not given, Answer not given (RngAng). On a test of immediate learning, the RngAng group had the poorest score. The other groups were not significantly different. The RngAg and RgAng groups were superior on retention and transfer tests. Wittrock interpreted this finding as evidence that an intermediate amount of guidance produced superior performance on retention and transfer.

Forgus and Schwartz (1957) attempted to test the validity of earlier Katona studies using a new 26-symbol alphabet. Female college students served as Ss in this study. Three treatments were used. In Treatment O Ss were told the principle underlying construction of the alphabet; in Treatment P Ss were told there was a principle and were asked to describe it; and, in Treatment M Ss were asked to memorize the alphabet. Both P and O groups, though not significantly different from each other, were significantly higher than group M on both retention and transfer tests one week after training.

Kersh in two studies (1958, 1962) examined the effects of guidance. In the 1958 study, Kersh used three treatments: No Help, Direct Reference (Ss were given perceptual aids), and Rule Given. The task consisted in verbalizing mathematical generalizations, and applying them to new problems. Ss were college students. The dependent measures in which Kersh was interested were retention, transfer, and heuristic S used to solve problems on a retest. The data failed to support the hypothesis that the Direct Reference Group would be superior on a test of retention and transfer. An additional finding of interest was that among 13 Ss in the No Help group who failed to discover the rule during the learning period, but who were retested after four weeks, ten used acceptable methods. This is in contrast to the other treatment groups in which there was a decrease in use of acceptable methods from test to retest. Kersh attributed this to a differential motivation level as a function of treatments and concluded that motivation was a more important factor than understanding in the effects of discovery learning. Kersh's second study (1962)

was designed to examine this motivational effect. The task was the same as in the previous study but Ss were high school students. Three treatments were used: Directed Learning, Guided Discovery, and Rote Learning. Ss in the Directed Learning group were given programmed booklets which presented the rules and explanations of the rules. Ss in the Guided Discovery group discovered the explanations under a Socratic method of teaching, and were presumed to be most highly motivated; Ss in the Rote Learning group were apparently not given an explanation of the rules. Results showed the Rote learning group to be superior on all measures to the other groups. The Guided Discovery Group was superior to the Directed Learning Group on all measures. Kersh's characterization of the Rote Learning treatment is rather difficult to accept, however, and it is this author's opinion that the Rote Learning group may, in fact, have been a "pure" discovery group.

Gagné and Brown (1961) assigned ninth- and tenth-grade boys to three experimental groups: Rule and Example (R & E), Discovery (D), and Guided Discovery (GD). The task consisted of learning several mathematical series. The GD group performed significantly better than the D group and the R & E group; the D group, however, performed significantly better than the R & E group.

This author finds it impossible to reconcile the results of the studies just cited. One may find some evidence for the superiority of none, some, or much guidance. More studies show some guidance or an intermediate amount of guidance to be more effective in terms of transfer than none or a large amount. However, this is probably

somewhat misleading since it is probable that the kind of guidance is at least as important as amount. For instance, Klausmeier and M... (1968) have shown that providing a principle produces better learning. In the Craig (1953), Craig (1956), Kittel (1957) and Wittrock (1963) studies, the groups which were given what could be called a principle performed best whether their designation was maximum amount of guidance (Craig 1953, 1956) or intermediate amount of guidance (Kittel 1957, Wittrock 1963). This suggests that additional work needs to be done varying the kind of guidance as well as the amount of guidance.

Effects of Verbalization on Discovery

Only three studies to date have examined this aspect of discovery. Hendrix (1947) used high school and college Ss and three treatments. In Method 1 Ss were told the principle. In Method 2 Ss were given a series of problems leading to discovery of the principle, but were not asked to verbalize it. Method 3 required Ss to verbalize the principle. Differences among the groups were not significant, but appeared to favor the non-verbalizing group. Schwartz (1948) examined the importance of verbalization in concept formation and found that even among most Ss who learned the concept and who could transfer to another sorting concept using the same principle, they were unable to verbalize the principle they were using; that unsuccessful attempts at verbalization negatively affected performance on subsequent tasks; and those who could verbalize the principle were successful on subsequent tasks. Gagné and Smith (1962) used the three-circle problem used by Ewert and Lambert (1932) and examined the effects of verbalization and solution set (instructions to search

for principle). Results showed no effects of solution set but the verbalization groups were significantly superior on number of moves and time to criterion. Not enough data is yet at hand to warrant conclusions about the effect of verbalization on discovery learning.

In summary what the literature to date has shown is that discovery learning is superior to rote learning on measures of long term retention and transfer, but not superior on measures of immediate acquisition. When the dimensions of amount of guidance and verbalization are introduced, however, complex interactions between stimuli and as yet undetermined variables appear to occur such that definitive statements are unwarranted at this time.

Chapter 4

METHOD

This experiment was designed to investigate the effects on retention and transfer of two methods of presenting selected geometry concepts to sixth graders. The effects on retention were measured at three points: 1 day after completion of the lessons, 11 days after completion of the lessons, and 21 days after completion of the lessons. The effect on transfer was measured immediately after completion of the last lesson. Assessment of the effect of method of presentation on immediate acquisition of the selected concepts was also measured immediately after completion of the lessons.

A pilot study was run to answer logistical questions regarding administration of the lessons and test, pinpoint problems in the procedure, and test for effects of the lessons. The methodology of the main study was based on the results of the pilot study.

Pilot Study

Subjects

Ss were 41 sixth-grade students at Poynette Middle School. The sample contained two classes, one of 19 Ss and one of 22 Ss. Both classes had the same teacher for mathematics instruction. None of the Ss had had previous contact with the concept being presented as part of school's instructional program.

Procedure

Ss in each class were randomly assigned to one of five groups. The groups were equivalent to proposed Groups 1, 4, 7, 10, and 13, respectively, in the main study. Table 1 shows the Groups and lesson and test sequence.

Table 1

Lesson and Test Sequence for each Group in the Pilot Study

Group	Day 1	2	3	4	5	6
1	Intro Lesson 1	Intro Lesson 2	½ Quad Lesson (D)	½ Quad Lesson (D)	Test 2	
2	Intro Lesson 1	Intro Lesson 2	½ Quad Lesson (E)	½ Quad Lesson (E)	Test 2	
3	Intro Lesson 1	Intro Lesson 2	Triangle Lesson (D)	½ Quad Lesson (D)	½ Quad Lesson (D)	Test 2
4	Intro Lesson 1	Intro Lesson 2	Triangle Lesson (E)	½ Quad Lesson (E)	½ Quad Lesson (E)	Test 2
5	Placebo	Placebo	Placebo	Placebo	Test 2	

Note: (D) Following a lesson denotes that it was presented in the discovery mode
(E) Following a lesson denotes that it was presented in the expository mode

All Ss except those in Group 5, the control group, were presented two introductory geometry lessons. Group 1 was then presented a lesson on quadrilaterals, administered in two parts on two successive days. in the discovery mode. Group 2 was presented a lesson on quadrilaterals, administered in two parts on two successive days, in the expository mode. Group 3 was presented a lesson on triangles in the discovery

mode. Group 4 was presented a lesson on triangles in the expository mode. This was followed by a lesson on quadrilaterals, again administered in two parts on two successive days, but in the expository mode. Group 5, the control group, received placebo lessons dealing with materials unrelated to geometry. All _Ss_ were tested 24 hours after completion of the last lesson.

Materials

GEOMETRY LESSONS

INTRODUCTORY LESSON 1. This lesson introduced the concepts _point_, _line segment_, _line_, _ray_, _angle_, _right angle_, _acute angle_, and _obtuse angle_.

INTRODUCTORY LESSON 2. This lesson introduced the concepts _closed curve_, _simple curve_, _plane_, _polygon_, _parallel_, _adjacent_, _opposite_, and _equal length_. This lesson also demonstrated how the student should use a ruler to identify angles and to check if lines were parallel. The format of Introductory lessons 1 and 2 was modified linear programming which required the child to respond to questions regarding the concepts introduced, with immediate feedback provided.

TRIANGLE LESSON (Expository and Discovery). Seven concepts were introduced in the lesson: _triangle_, _equilateral triangle_, _isosceles triangle_, _scalene triangle_, _right triangle_, _obtuse triangle_, and _acute angle triangle_. To present each concept six examples were used, four positive and two negative. The negative examples isolated the relevant attributes and the positive examples the irrelevant attributes.

For example, the concept quadrilateral has one relevant attribute which distinguishes it from other polygons, that is that it has four and only four sides. Size, shape, orientation, or relative length of the sides are irrelevant attributes. The two negative examples (triangle and pentagon) focus attention on number of sides in that all positive examples have four sides while the negative examples have three and five, respectively. The four positive examples vary on the dimensions of size, shape, orientation and relative length of sides indicating the non-relevance of these dimensions to identification of the concept. The sequence of positive and negative instances was the same for each concept, i.e., +, -, +, -, +, +. The concepts were presented in this manner and sequence in both the expository and discovery lessons. The difference between the lessons lay in the statements accompanying each example. In the expository lesson each example was accompanied by a statement such as this, "Look at this figure. Note that side AB is equal to AC; AB is 1"; AC is 1"." In the discovery lesson each example was accompanied by a statement such as this "Look at this figure. Measure side AB. Measure side AC. What do you find?"

QUADRILATERAL LESSON (Expository and Discovery). Seven concepts were introduced in this lesson: quadrilateral, rhombus, parallelogram, trapezoid, rectangle, square, and kite. The manner of introducing each concept and the number and sequence of examples was exactly as described above for the triangle lessons. The difference between the discovery and expository mode of presenting the

material was the same as that described for the triangle lesson.

Placebo Lessons

LESSON 1. This lesson explained the formation of Roman numerals for the numbers 1 through 1100.

LESSON 2. This lesson introduced the numeration system in base 10 for numbers having up to seven digits.

LESSON 3. This lesson presented the commutative and associative properties and the identity element in addition and multiplication.

LESSON 4. This lesson presented subtraction as the inverse of addition and explained the regrouping process in subtraction.

Tests

TEST 1. This test was embedded in the lesson on quadrilaterals. The items, multiple choice items taken from a test developed by Frayer (1969), were presented immediately upon completion of the material dealing with each concept and referred to that concept only. Five item types, one question per item type for the each of the concepts quadrilateral, rhombus, parallelogram, trapezoid, rectangle, square, and kite, constituted the test. Item type 1 required recognition of an attribute example, given the attribute name; type 3 required recognition of a concept example, given the concept name; type 5 required recognition of the concept name, given an example; type 9 required recognition of the concept definition given the concept name; and, type 10 required recognition of a supraordinate concept, given the concept name. This

test was designed to measure initial acquisition of the concepts. TEST 2. This test was administered 1 day after completion of the lessons in order to measure retention of the concepts. The items on the test were similar to those on Test 1, but required production of the answers. Items were selected from a test developed by Frayer (1969). Both Test 1 and Test 2 contained thirty-five items.

Design

The pilot study included five treatment groups. These groups were defined by the lesson sequences noted in Table 1. Class was included as a blocking factor in the design. Ss were therefore randomly assigned to treatment group within class. The dependent variables were the total scores on Test 1 and Test 2.

Outcome of the Pilot Study

Detailed results of the pilot study will be reported in Chapter 5. The following summary is presented as a background for the changes in methodology effected in the main study.

1. The quadrilateral lesson alone was insufficient to produce any effect. Groups 1 and 2 were not significantly different from the control group (Group 5). Additional examples for each concept were therefore included in the lessons used in the main study.

2. Superior performance of both groups which received the triangle lessons (Groups 3 and 4) suggested that additional interaction with this kind of material is important. This reinforced the decision to add additional examples to the quadrilateral lesson.

3. An analysis of Test 2 by concept and item type as shown in Figure 1 indicated that not all concepts or item types discriminated between treatment groups. It appeared that the control group was sufficiently familiar with the concepts square and rectangle to render these concepts nondiscriminating. The concept kite was too difficult for all groups and was therefore nondiscriminating. This precipitated the decision to drop these concepts from the main study. Item types 9 and 10 appeared too difficult for all groups. Item type 10 was dropped from the tests in the main study. Item type 9 was retained as insurance against ceiling effects.

4. The transfer groups (Groups 3 and 4) showed no effect of transfer on Test 1, the test of immediate acquisition when compared with the control group. The differences showed up on Test 2, 24 hours later. It was not possible to determine whether this was a real effect or an artifact resulting from the use of tests which were not parallel. This finding led to the decision to make Test 1 and Test 2 parallel so that some judgment might be made should such an effect appear in the main study. This result also led to the decision not to use Test 1 as measure of transfer, but to use instead Test 2 administered immediately after completion of the last les n.

5. The finding that there was no difference among groups on Test 1 was noted with some relief, since it is well known (Underwood, 1964) that differences in degree of initial learning lead to predictable differences in retention scores. Based on results of the pilot study, it was expected that the level of initial learning would not differ among groups in the main study.

Concept	1	3	6	9	10
Square			x		
Rectangle	x				
Rhombus	x	x	x		
Parallelogram	x	x	x		
Kite	x	x			
Trapezoid	x	x	x		
Quadrilateral	x	x	x		

Item Type

Fig. 1. Analysis of Test 2 by item type and concept indicating items which discriminated among groups. (An item was considered to discriminate among groups if one group had three more incorrect items than any other group.)

Main Study

Subjects

Ss were 256 sixth-grade students from six Stevens Point, Wisconsin schools. Eleven classes which had had no prior training on the concepts being presented were used. The initial sample consisted of 300 Ss. 43 Ss were lost through absence from one or more of the lessons, or from the final test. One S was lost because he received an incorrect sequence of lessons. Thus, 256 remained and the results are based on the data from these 256 Ss. Tables 2 and 3 show the distribution of Ss by school and treatment condition.

Table 2

Number of Subjects in Experiment 1 by School and by Treatment Condition

School	Treatment Condition 1	2	3	4	5	6	7	8	9
1	2(1)	2(1)	3(0)	2(1)	2(1)	2(1)	3(0)	3(0)	3(0)
2	3(1)	4(0)	4(0)	4(0)	4(0)	2(2)	4(0)	2(2)	4(0)
3	4(1)	4(0)	4(0)	5(0)	4(0)	4(1)	3(2)	4(0)	4(0)
4	4(0)	4(0)	3(0)	3(0)	4(0)	4(0)	4(0)	4(0)	4(0)
5	2(2)	4(0)	3(0)	3(0)	2(1)	3(1)	4(0)	3(1)	2(1)
6	1(0)	1(0)	2(0)	1(0)	0(2)	1(0)	1(0)	2(0)	0(1)
Total	16(5)	19(1)	19(0)	18(1)	16(4)	16(5)	19(2)	18(3)	17(2)

Note. - The number of subjects lost due to absence or procedural error are given in parenthesis.

Table 3

Number of Subjects in Experiment 2 by School and by Treatment Condition

School	Treatment Condition 10	11	12	13	14	15	Total
1	1(2)	2(1)	1(2)	2(2)	3(0)	3(0)	34(12)
2	2(1)	3(1)	3(1)	4(0)	3(0)	4(0)	50(8)
3	4(1)	3(1)	4(0)	3(1)	3(1)	4(0)	57(8)
4	3(1)	2(1)	3(0)	3(0)	3(1)	4(0)	52(3)
5	4(0)	3(1)	2(2)	3(1)	4(0)	4(0)	46(15)
6	1(0)	2(0)	2(0)	1(0)	1(0)	1(0)	17(3)
Total	15(5)	15(5)	15(5)	16(4)	17(2)	20(0)	256(44)

Note. - The number of subjects lost due to absence or procedural error are given in parentheses.

Procedure

Ss were randomly assigned within school to the 15 treatment groups. Experiment 1, which dealt with the effects of method of presentation on retention, had nine groups. Ss in Groups 1 to 6 were given two introductory geometry lessons. Groups 1, 2, and 3 were then presented lessons on quadrilaterals in the discovery mode; Group 1 was tested 1 day after presentation of the last lesson, Group 2 was tested 11 days afterwards, and Group 3, 21 days afterwards. Groups 4, 5, and 6 were presented lessons on quadrilaterals in the expository mode, Group 4 being tested 1 day later; Group 5 11 days later; and Group 6, 21 days afterwards. Groups 7, 8, and 9, the control groups, received placebo lessons on materials unrelated to geometry and were tested at the same times as the 1-day, 11-day, and 21-day groups above.

Experiment 2, which dealt with the effects of method of presentation on transfer and initial acquisition, had six groups. Ss in Groups 10-15 were given two introductory geometry lessons. Groups 10 and 11 were then presented a lesson on triangles in the discovery mode; following the triangle lesson, Group 10 was presented lessons on quadrilaterals in the discovery mode, while Group 11 was presented lessons on quadrilaterals in the expository mode. Groups 12 and 13 were presented a lesson on triangles in the expository mode; following the triangle lesson, Group 12 received lessons on quadrilaterals in the discovery mode, while Group 13 received lessons on quadrilaterals in the expository mode. Groups 14 and 15, the control groups for the transfer experiment, did not receive lessons on triangles; Group 14

received lessons on quadrilaterals in the discovery mode and Group 15 received lessons on quadrilaterals in the expository mode. Groups 10 through 15 were tested immediately on completion of the last lesson. Tables 4 and 5 show the group, and lesson and test sequence for each of the treatment groups.

All materials were pre-packaged by day, school, and class with _Ss_' names on the booklets to insure correct sequence of lessons. The procedure for each lesson was as follows. The proctor distributed pencils, rulers and booklets. Instructions concerning procedure to be followed in completing the lessons were given and difficult words in the lessons, listed on the opening page, were pronounced for the class. Students were then instructed to record the starting times and commence work. After _S_ had completed the lesson, he worked at his desk on an assignment given by his teacher until all _Ss_ had completed the lesson. Booklets, pencils, and rulers were then collected. Instructions for the lessons and test comprise Appendix B.

Two proctors were used. _E_ proctored the lessons in two classes each at Roosevelt and McDill, and one class at McKinley school. A substitute teacher from the Stevens Point school system proctored the lessons in two classes each in Emerson, Madison, and Washington schools. Since the experiment was being conducted in both groups of schools at the same time, _E_ could not monitor the procedures used by the substitute teacher. A check by an independent observer was, therefore, made to insure uniformity of the procedures being used. Procedures were adjudged by the observer to be uniform across schools and proctors.

Table 4

Lesson and Test Sequence for Each Group in Experiment 1

	Day 1	2	3	4	5	15	25
Group 1	Intro Lesson 1	Intro Lesson 2	½ Quad Lesson (D)	½ Quad Lesson (D)	Test Q		
Group 2	Intro Lesson 1	Intro Lesson 2	½ Quad Lesson (D)	½ Quad Lesson (D)		Test Q	
Group 3	Intro Lesson 1	Intro Lesson 2	½ Quad Lesson (D)	½ Quad Lesson (D)			Test Q
Group 4	Intro Lesson	Intro Lesson 2	½ Quad Lesson (E)	½ Quad Lesson (E)	Test Q		
Group 5	Intro Lesson 1	Intro Lesson 2	½ Quad Lesson (E)	½ Quad Lesson (E)		Test Q	
Group 6	Intro Lesson 1	Intro Lesson 2	½ Quad Lesson (E)	½ Quad Lesson (E)			Test Q
Group 7	Placebo	Placebo	Placebo	Placebo	Test Q		
Group 8	Placebo	Placebo	Placebo	Placebo		Test Q	
Group 9	Placebo	Placebo	Placebo	Placebo			Test Q

Note - (D) denotes that the lesson was presented in the discovery mode.
(E) denotes that the lesson was presented in the expository mode.

Table 5

Lesson and Test Sequence for Each Group in Experiment 2

	Day 1	2	3	4	5
Group 10	Intro Lesson 1	Intro Lesson 2	Triangle Lesson (D)	½ Quad Lesson (D)	½ Quad Lesson (D) & Test Q
Group 11	Intro Lesson 1	Intro Lesson	Triangle Lesson (D)	½ Quad Lesson (E)	½ Quad Lesson (E) & Test Q
Group 12	Intro Lesson 1	Intro Lesson 2	Triangle Lesson (E)	½ Quad Lesson (D)	½ Quad Lesson (D) & Test Q
Group 13	Intro Lesson 1	Intro Lesson 2	Triangle Lesson (E)	½ Quad Lesson (E)	½ Quad Lesson (E) & Test Q
Group 14	Intro Lesson 1	Intro Lesson 2	½ Quad Lesson (D)	½ Quad Lesson (D) & Test Q	
Group 15	Intro Lesson 1	Intro Lesson 2	½ Quad Lesson (E)	½ Quad Lesson (E) & Test Q	

Note - (D) denotes that the lesson eas presented in the discovery mode.
(E) denotes that the lesson was presented in the expository mode.

Material

Geometry Lessons.

INTRODUCTORY LESSONS 1 AND 2. These were the same as the introductory lessons used in the pilot study with minor modifications. The concept adjacent was dropped from Introductory Lesson 2 since the concept kite for which it was a prerequisite was dropped from the quadrilateral lessons. Modifications were made in the wording of items where data from the pilot study suggested ambiguity or confusion. Therefore, in this study Introductory Lesson 1 introduced the concepts point, line segment, line, ray, angle, right angle, acute angle, and obtuse angle. Introductory Lesson 2 introduced the concepts closed curve, simple curve, plane, polygon, parallel, opposite and equal length. The lesson also demonstrated how the student should use the ruler to identify angles and to check if lines were parallel. The format was modified linear programming, requiring the child to respond to questions regarding the concepts introduced, with immediate feedback provided.

TRIANGLE LESSON. With the exception of minor modifications in wording, and the removal of the concept scalene triangle to reduce lesson time, this lesson was exactly like that used in the pilot study. Concepts presented in this lesson were: triangle, equilateral triangle, isosceles triangle, right triangle, obtuse triangle, and acute angle triangle. As in the pilot study, six examples were used, four positive and two negative. The examples were sequenced as follows: +, -, +, -, +, +. The expository lesson again stated the attributes of the concept, while the discovery lesson directed the student to look at

the examples and asked him to produce attributes.

QUADRILATERAL LESSON. Based on the findings of the pilot study, this lesson underwent the most change. Three of the concepts used in the pilot study were found to be either too easy or too difficult and were eliminated. The failure of students receiving this lesson in the pilot study to achieve a higher score than the control group, coupled with the finding that the group receiving the additional triangle lesson performed significantly better than the control group gave rise to the hypothesis that there was insufficient interaction by students in the retention groups with this type of material. It was, therefore, decided to double the number of examples. Consequently, only four concepts were introduced in this lesson: quadrilateral, rhombus, parallelogram, and trapezoid. The concepts quadrilateral and rhombus were presented first using six examples, four positive and two negative in the following sequence +, -, +, -, +, +. After the two concepts were presented in the above fashion, the first concept was presented again using six examples in the sequence +, -, +, -, +, =, but using different examples from those in the first sequence.

The negative examples isolated the relevant attributes, while the positive examples isolated the irrelevant attributes as described for the pilot study lessons. Thus a total of twelve examples of each concept was used. The concepts were presented in this manner and sequence in both the expository and discovery lessons. The difference between the lessons lay in the statements accompanying each example. In the expository lesson each example was accompanied by a statement such as this: "Look at this figure. Note that side

AB is equal to AC; $\overline{AB}$ is 1"; $\overline{AC}$ is 1". In the discovery lesson each example was accompanied by a statement such as this; "Look at this figure. Measure the side AB Measure the side AC. What do you find?" Each lesson also contained an embedded test as described below. The quadrilateral lesson was again presented in two parts to all groups. The first part presented the concepts quadrilateral and rhombus, the second presented the concepts parallelogram and trapezoid, in the same manner as that described for quadrilateral and rhombus.

The lessons were presented in prepared booklets similar to those used in Introductory Lessons 1 and 2, except that in Lessons 1 and 2 questions were asked during the presentation of the concept and immediate feedback given. In the triangle and quadrilateral lessons, the expository lessons contained no questions. The discovery lessons contained questions but provided no feedback during the lesson. Feedback was provided to two general questions at the end of the presentation of each concept. Appendix C contains the concept parallelogram presented in both the discovery and expository modes.

Placebo Lessons

LESSON 1. This lesson explained the formation of Roman numerals for the numbers 1 through 1100.

LESSON 2. This lesson introduced the numeration system in base 10 for numbers having up to seven digits.

LESSON 3. This lesson presented the commutative and associative properties and the identity element in addition and multiplication.

LESSON 4. This lesson presented subtraction as the inverse of addition and explained the regrouping process in subtraction.

Tests

EMBEDDED TEST (Test E). This test was a production test which required S to produce a word or a definition or complete a figure. Five types of items were used, type 1 required production of an attribute example, given the attribute name; type 3 required production of a concept example, given the concept name; type 4 required production of a concept non-example, given the concept name; type 6 required production of the relevant attribute, given the concept name; and type 9 required production of the concept definition, given the concept name. For each concept, there was one item each of types 1, 6, and 9, two items each of types 3 and 4 for a total of 28 items. The function of Test E was to provide a measure of original learning for Groups 1-9. Although it was not logically required for Groups 10-15, it was administered in order to give them a comparable set for later testing.

QUADRILATERAL TEST (Test Q). This test was a multiple-choice test administered to Ss in all treatment groups. Test Q was parallel to Test E, in content, item types, and number of items (28), but required recognition rather than production of answers. Psychometric characteristics of this test are reported in Chapter 5.

Design

Experiment 1. The design of this experiment was a 3 X 3 factorial with three types of lessons (discovery, expository,

and placebo) and three retention intervals (1 day, 11 days, and 21 days). This design is illustrated in Table 6. School was included as a blocking factor. Ss were, therefore, randomly assigned to treatment within school. The dependent variable was the total score on Test Q. Covariates were the score on Test E, IQ, and the math achievement score of the Iowa Test of Basic Skills.

Table 6

Experimental Design of Experiment 1

Independent Variables	
Type of Lesson	Retention Interval
Quadrilateral Lesson (D) (Discovery)	1 day 11 days 21 days
Quadrilateral Lesson (E) (Expository)	1 day 11 days 21 days
Placebo Lesson	1 day 11 days 21 days

Experiment 2. The design of this experiment was a 3 x 2 factorial with three types of initial lesson (triangle lesson-discovery, triangle lesson-expository, and no triangle lesson) and types of subsequent lesson (quadrilateral lesson-discovery and quadrilateral

lesson-expository). This design is illustrated in Table 7. School was included as a blocking factor. Ss were, therefore randomly assigned to treatment within school. The dependent variable was the total score on Test Q. Covariates were the score on Test E, IQ, and the math achievement score of the Iowa Test of Basic Skills.

Table 7

Experimental Design of Experiment 2

Independent Variables	
Initial Lesson	Subsequent Lesson
Triangle Lesson (D) (Discovery)	Quadrilateral Lesson (D) (Discovery)
Triangle Lesson (D) (Discovery)	Quadrilateral Lesson (E) (Expository)
Triangle Lesson (E) (Expository)	Quadrilateral Lesson (D) (Discovery)
Triangle Lesson (E) (Expository)	Quadrilateral Lesson (E) (Expository)
No Triangle Lesson	Quadrilateral Lesson (D) (Discovery)
No Triangle Lesson	Quadrilateral Lesson (E) (Expository)

Chapter 5

RESULTS

Pilot Study

One dependent measure, the total score on Test 2, was obtained for each *S*. Table 8 shows the number of subjects, and means and standard deviations for scores on Test 2 of each treatment group within each class. Figure 2 shows the mean total score on Test 2 as a function of treatment condition. Analysis of variance of the scores on Test 2 indicated that the performance of both Groups 4 and 5 (transfer groups) was significantly better than the control group. The average score of Groups 4 and 5 was significantly better than the average score of Groups 1 and 2, indicating a positive transfer effect as a function of the presentation of the prior lesson. No other comparisons were significant. No class effect was noted, and there was no class by treatment interaction. Results of the analysis of variance of scores on Test 2 are presented in Table 9. No difference was found among experimental groups when the measure used was score on Test 1. The control group could not be compared with experimental groups on this measure since Test 1 was not embedded in the Placebo lessons.

Main Study

Three scores were obtained for each S; the total score on Test Q, an IQ score, and a math ability score, the latter two to be used as covariates. A fourth score, the score on Test E, was obtained for all Ss except those in groups 7, 8, and 9, who received placebo lessons.

Psychometric Characteristics of Test Q

Data for 256 Ss who completed all lessons and Test Q were used to determine the psychometric characteristics of Test Q which are reported in this section. The test was analyzed by the Fortran Test Analyses Package (Baker & Martin, 1968). Statistics were computed both within and across schools. Table 10 shows the number of subjects, mean score, standard deviation, range, standard error of measurement and Hoyt reliability extimates (Hoyt, 1941) for Test Q scores within and across schools.

Table 8

Number of Subjects, Means, and Standard Deviations
of Total Scores on Test 2
by Treatment Group and by Class for the Pilot Study

	Treatment Groups				
Class	1	2	3	4	5
1	13.00	13.33	22.50	21.25	11.00
	(4.00)	(3.51)	(8.96)	(7.18)	(4.64)
	N=3	N=3	N=4	N=4	N=4
2	18.00	15.75	21.75	15.50	16.00
	(6.22)	(3.69)	(4.99)	(4.20)	(6.90)
	N=4	N=4	N=4	N=4	N=5

Note.-Standard deviations are given in parentheses.

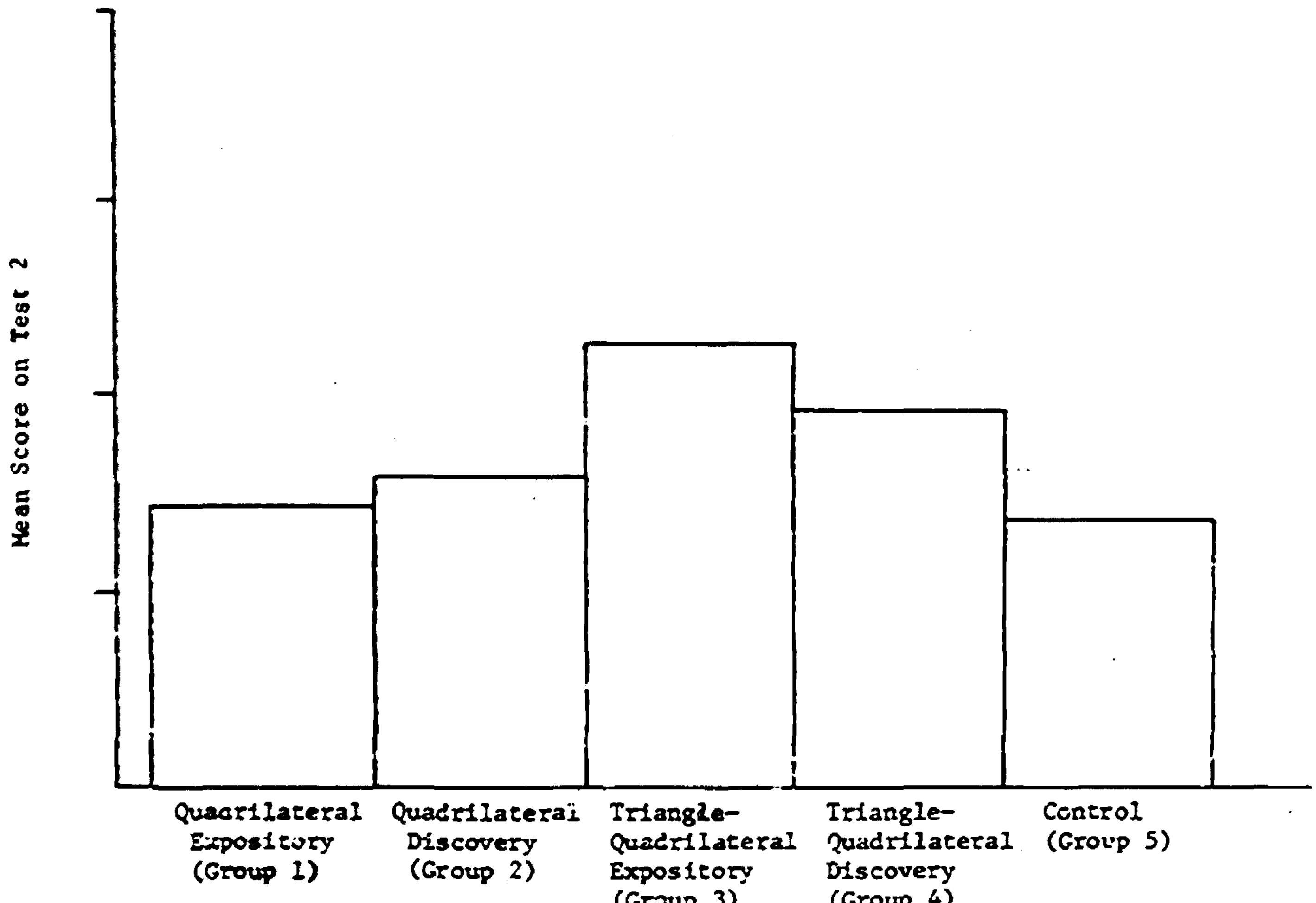

Fig. 2. Scores attained on Test 2 by Experimental and Control Groups in pilot study.

TABLE 9

Univariate Analysis of Effect of Presentation Method on Scores of Test 2 in the Pilot Study

Source	df	MS	F	
Class	1	1.1524	.0344	$p < .85$
1 + 2 vs. 3 + 4 (Q vs. TQ)[a]	1	182.87	5.45	$p < .03$ **
1 vs. 2	1	4.57	0.14	$p < .72$
3 vs. 4	1	56.25	1.68	$p < .21$
Interactions	3	40.04	1.20	$p < .4$
Control vs. Treatments Removing Class	1	56.00	1.67	$p < .25$
Error (Within Treatment only)	22	33.49	--	--

[a] Q = quadrilateral lesson only; TQ = Triangle lesson followed by quadrilateral lesson.

**Significant at or beyond the .05 level of significance chosen.

Table 10

Psychometric Characteristics of Test Q Within and Across Schools

School	Number of Subjects	Mean Score	Standard Deviation	Range of Scores[a]	Standard Error of Measurement	Hoyt Reliability
1	34	13.53	5.29	5-27	2.28	.81
2	50	16.20	6.15	5-27	2.24	.86
3	57	10.86	4.05	5-27	2.34	.65
4	52	12.83	6.01	4-28	2.27	.85
5	46	12.17	5.55	5-27	2.29	.82
6	17	13.18	6.29	6-27	2.26	.86
Total	256	13.05	5.73	4-28	2.29	.83

[a]Highest possible score was 28.

Analysis of Data

All analyses of variance and covariance were carried out using Finn's (1968) Multivariance or Multiple Regression [Regan 1] (Guha 1966) computer program. The dependent variable for all analyses was total score on Test Q. Covariates were IQ, arithmetic ability score and total score on Test E. Since the number of Ss in the cells varied, the design is non-orthogonal. Because of this, the effects are not independent and are estimated in stepwise fashion. The effects of greatest interest are ordered last so that unbiased estimates may be obtained.

Experiment 1

Experiment 1 examined the effects of two methods of presenting geometry lessons and of presenting material unrelated to geometry on Test Q scores, as a function of a 1-, 11- and 21-day retention intervals. This experiment included nine treatment groups: Groups 1, 2, and 3 in which Ss received lessons in the discovery mode and were tested at 1, 11, and 21 days, respectively; Groups 4, 5, and 6 in which Ss received lessons in the expository mode and were tested at 1, 11, and 21 days, respectively; Groups 7, 8, and 9 in which Ss received placebo lessons and were tested at 1, 11, and 21 days respectively. The number of subjects, means, and standard deviations for each of the nine treatment conditions within each school are presented in Table 10, 11, and 12. Figure 3 shows the combined mean total score on Test Q under each treatment as a function

of retention interval. Means for the discovery group increased as a function of time, while means for the expository groups decreased as a function of time. Both expository and discovery groups performed better at each retention interval than the control group. The number of subjects and the estimated combined means fore ach treatment group and for each school are shown in Table 13.

Table 11

Number of Subjects, Means and Standard Deviations of Treatment Groups 1-6 Within Each School

	Treatment Group					
	Discovery			Expository		
	1 day	11 day	21 day	1 day	11 day	21 day
School	1	2	3	4	5	6
1	15.00 (0.00) N=2	10.00 (2.82) N=2	18.33 (6.11) N=3	17.50 (6.36) N=2	11.50 (9.19) N=2	9.00 (2.82) N=2
2	12.00 (5.57) N=3	12.75 (6.07) N=4	20.00 (6.98) N=4	19.25 (5.12) N=4	13.75 (5.31) N=4	25.50 (2.12) N=2
3	10.00 (2.45) N=4	12.50 (3.11) N=4	11.25 (2.75) N=4	10.20 (3.77) N=5	8.50 (1.29) N=4	10.00 (4.24) N=4
4	12.50 (2.08) N=4	9.75 (2.99) N=4	20.67 (4.51) N=3	14.00 (9.85) N=3	18.00 (6.98) N=4	11.00 (4.24) N=4
5	8.00 (0.00) N=2	9.50 (2.38) N=4	7.33 (3.21) N=3	19.50 (0.71) N=2	21.67 (2.52) N=3	10.33 (1.15) N=3
6	12.00 (0.00) N=1	6.00 (0.00) N=1	11.00 (5.66) N=2	12.00 (0.00) N=1	0.00 (0.00) N=0	19.00 (0.00) N=1

Note.-Standard deviations are given in parenthesis.

Table 12

Number of Subjects, Means and Standard Deviations of Treatment Groups 7-9 Within Each School

School	Treatment Group Control group [illegible] day 7	 11 day 8	 [illegible] day 9
1	9.67 (5.03) N=3	9.33 (3.51) N=3	13.13 (2.08) N=3
2	13.75 (6.85) N=4	13.00 (1.41) N=2	15.50 (4.36) N=4
3	7.00 (1.00) N=3	9.75 (3.20) N=4	12.75 (4.35) N=4
4	7.50 (2.65) N=4	7.25 (4.57) N=4	8.50 (2.38) N=4
5	8.75 (2.63) N=4	7.33 (1.53) N=3	8.50 (4.95) N=2
6	10.00 (0.00) N=1	7.00 (1.41) N=2	0.00 (0.00) N=0

Note.-Standard deviations are given in parentheses.

Table 13

Number of Subjects and Combined Mean Total Scores on Test Q by Treatment Group and by School

Treatment Group[a]								
Discovery			Expository			Control		
1 day	11 day	21 day	1 day	11 day	21 day	1 day	11 day	21 day
1	2	3	4	5	6	7	8	9
12.29	10.58	14.90	14.93	14.35	12.91	9.17	9.02	11.65
N=16	N=19	N=19	N=17	N=17	N=16	N=19	N=18	N=17

School					
1	2	3	4	5	6
12.82	15.75	10.15	11.98	11.73	10.79
N=22	N=31	N=36	N=34	N=26	N=9

[a]Treatment means were obtained by averaging school means within each treatment, giving equal weight to each school and thus removing the effect of unequal numbers of students within each school.

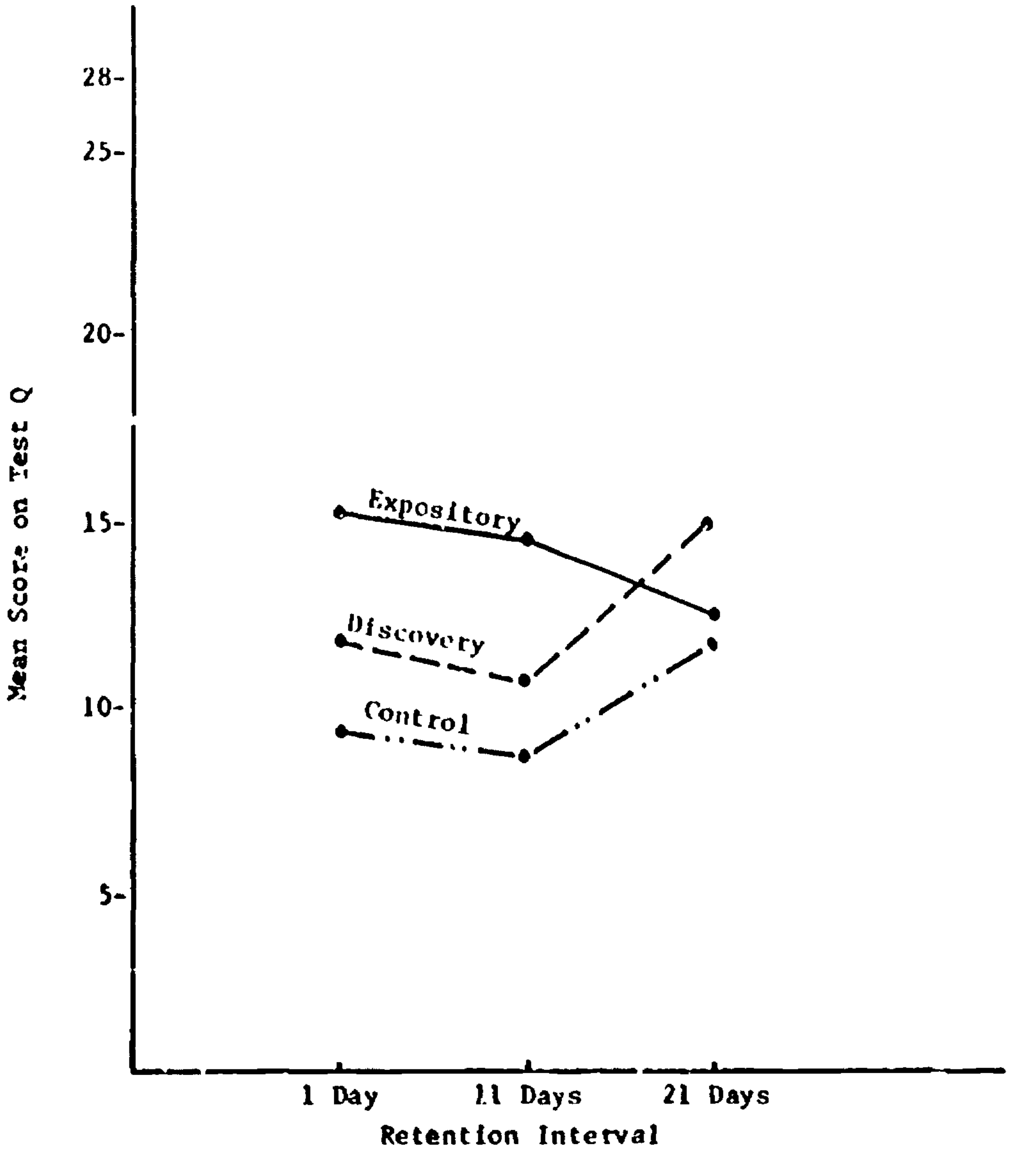

Fig. 3. Mean scores of Expository, Discovery and Control Groups 1, 11 and 21 days after completion of lessons.

An analysis of variance was performed on the data summarized above. The results of this analysis are shown in Table 14. The following comparisons were made with effects as noted. Performance on Test Q of both discovery and expository groups combined was compared with performance of the control group over all retention intervals. This test was made to determine whether or not any learning was effected by the learning materials. Treatment groups performed significantly better than control groups indicating that Ss had learned from the prepared materials. Performance of the expository and discovery groups was compared to determine differential effects of presentation method. Considered ever all retention intervals, the performance of the expository group was significantly better than the discovery group. The interaction of discovery and expository group and retention interval was, however, also significant. This would indicate that method of presentation did significantly affect the retention of the lesson material, the expository method effecting a net loss over time but the discovery method resulting in a net gain. The effect of retention interval alone was not significant. This was probably due, however, to the fact that scores increased for the discovery group, decreased for the expository group and gained slightly for the control group. When these scores are combined at each retention interval, the means become almost the same at each retention interval and the null hypothesis was, therefore, not rejected. There was no interaction of discovery expository and control groups with retention interval.

There were a number of effects due to school. The effect of school was significant, as were interactions of school X treatment condition and school X retention interval. Because of two empty cells in School 6, data from this school were not analyzed with that from the others. The procedure used was to compare the effects in school 6 with the total effects in the other five schools. This procedure necessitated assuming one school X treatment interaction (school 6) to be zero. No significant effect specific to school 6 was found. Effects involving school were removed from the model before testing of other treatment effects.

Table 14

Univariate Analysis of Variance for Effect of Presentation Method on Scores on Test Q

Source of Variation	df	MS	F-ratio	Probability	
Schools	5	123.81	6.59	<.0001	**
School X Treatment Conditions[a]	33	37.29	1.98	<.025	**
School X Treatment	8	49.18	2.62	<.01	**
School X Retention Interval	8	44.71	2.38	<.02	**
School X Retention Interval X Treatment	17	28.20	1.50	<.11	
Treatment vs. Control	1	174.30	9.27	<.0005	**
D vs. E	1	99.17	5.28	<.01	**
Retention Interval	2	7.16	0.38	<.68	**
Treatment vs. Control X Retention Interval	2	10.88	0.57	>.05	**
D vs. E x Retention Interval	2	111.64	5.94	<.05	
Residual (Specific to School 6)	4	28.47	1.51	<.20	**
Error	105	18.80	-		

[a]Because of missing cells, certain school by treatment interactions were assumed to be zero. All missing cells occurred in school 6. One interaction was assumed now-zero in that school.

** significant at or beyond the .05 level chosen.

An analysis of covariance with score on Test Q as the dependent measure and scores on Test E, arithmetic ability, and IQ as covariates. Results of the analysis of covariance are shown in Table 15. Use of Test E as a covariate excluded groups 7, 8, and 9 from the analysis since Test E was not embedded in the placebo lessons. The score on Test F was used as a covariate since it is well-documented in the psychological literature (Underwood, 1964) that degree of original learning affects rate of forgetting. One method of attempting to statistically equalize degree of original learning is to remove effects of original learning, as measured by Test E, from the model prior to making a test of retention effects. This procedure was followed here.

All of the covariates are highly correlated with one another as might be anticipated. It was expected that the covariates would be relatively highly correlated with school, and might, therefore, reduce the school effects in the analysis. This did not prove to be the case, however.

IQ was not related to either school or treatment condition. The overall relation of the arithmetic ability score to schools and treatment was not significant. Test E scores were associated both with D vs. E and schools. Inclusion of the three covariates did reduce the sums of squares attributable to schools and school x treatment interactions but did not eliminate these effects altogether, since both were significant even with the covariates in the model.

Table 15

Univariate Analysis of Covariance for Effect of Presentation Method on Scores on Test Q

Source of Variation	df	MS	F ratio	Probability
Mean	1		-	
Schools	5	95.47	7.06	<.0005 **
Covariates				
Linear-Total	3	382.66	28.31	<.0005 **
Math & IQ	2	428.50	31.70	<.0005 **
Test E	1	291.00	21.53	<.0005 **
School X Treatments[a]	24	29.77	2.20	<.025 **
Covariates - Non Linear	6	11.06	0.82	<.25
(Treatments Total	5	47.05	3.48	<.025)
D vs. E x Retention Interval (Total)	2	72.16	5.34	<.01 **
Non Linear	1	32.23	2.38	<.15
Linear	1	112.10	8.29	<.01 **
Retention Interval Total	2	15.47	1.14	>.1
Non Linear	1	27.93	2.07	>.1
Linear	1	3.01	0.22	>.1
D vs. E	1	59.98	4.44	<.05 **
Covariates X Treatments	15	15.49	1.15	<.5
Residual (for error)	45	13.52	-	-

[a]To make treatment effects estimable one treatment X school interaction (School 6) was assumed zero.

**significant at or beyond the .05 level chosen.

Results of the analysis of covariance confirmed the findings of the analysis of variance. Performance on Test Q of discovery and expository groups combined was compared with performance of the control group over all retention intervals. Treatment groups performed significantly better than control group confirming that Ss had learned from the prepared materials. Performance of discovery and expository groups was compared to determine differential effects of presentation method. Considered over all retention intervals, the performance of the expository group was significantly better than the discovery group. The interaction of discovery and expository groups and retention interval, was also significant, again indicating that method of presentaion significantly and differentially affected the retention of the lesson material. The effect of retention interval alone was not significant, again probably due to the increase of the scores of the discovery group being cancelled by the decreasing scores of the expository group. There was again no interaction of discovery, expository and control groups with retention interval. School effects and school x treatment interaction were significants as were the effects of each of the three covariates. A test for interaction of covariates with treatment was not significant. Effects were removed from the model in the order listed in Table 14 with the effects of interest being removed last.

Experiment 2.

This experiment was performed to assess the effect of presenting a lesson on triangles in either the expository or discovery mode on

learning of a subsequent lesson on quadrilaterals presented in the expository or discovery mode. Learning was measured by the score on Test Q. The design included six treatment groups (see Table 5) as follows. In Group 10 Ss received a lesson on triangles in the discovery mode followed by a lesson on quadrilaterals, in the discovery mode (Group DD). In Group 11 Ss received a lesson on triangles in the discovery mode followed by a quadrilateral lesson in the expository mode (Group DE). In Group 12 Ss received a lesson on triangles in the expository mode followed by a quadriteral lesson in the discovery mode (Group ED) followed by a quadrilateral lesson also in the expository mode, (Group ED). In Group 13 Ss received a triangle lesson in the expository mode, followed by a quadrilateral lesson also in the expository mode (Group EE). Group 14 Ss received a lesson on quadrilaterals only, in the discovery mode (Group D), and Group 15 received a quadrilateral in the expository mode (Group E). No effects of transfer were found. Table 16 lists the number of subjects, means, and standard deviations for each treatment condition within each school. Table 17 presents the combined means for each treatment and school. Figure 4 shows the mean scores on Test Q for each treatment condition. Examination of this figure suggests that presenting a lesson in the discovery mode first, produces negative transfer when the second lesson was in the discovery mode, but positive transfer when the second lesson was in the expository mode. Presenting a lesson in the expository mode first appeared to produce positive transfer when the second lesson

was also in the expository mode but negative transfer when the second lesson was in the disvoery mode. None of the transfer effects were significant, however on an analysis of covariance.

An analysis of covariance was run with score on Test Q as the dependent measure and scores of Test E arithmetic ability and IQ as covariates. Results of the analysis of covariance are shown in Table 18. These results showed a significant school effect, and a significant effect ofthe covariates. School X treatment and Covariate X Treatment interactions were not significant. Tests were made for transfer effects (DD-D and EE-E), and interference effects (ED-D and DE-E). Neither test was significant at the chosen alpha level. Tests for interaction between transfer and method of presentation, and between interference and method of presentation were also not significant.

A $\underline{t}$ test was performed on the means of groups 14 and 15 to examine the effects of discovery and expository methods of presentation on immediate acquisition. The difference was not significant at the .05 level.

Table 16

Number of Subjects, Means, and Standard Deviations of Treatment Groups 10-15 Within Each School

School No.	Treatment Group 10	11	12	13	14	15
1	22.00 (0.00) N=1	16.00 (1.41) N=2	14.00 (0.00) N=1	19.00 (11.31) N=2	14.00 (4.36) N=3	11.33 (3.21) N=3
2	10.00 (7.07) N=2	19.00 (4.00) N=3	14.67 (6.51) N=3	20.00 (4.69) N=4	12.67 (4.04) N=3	19.50 (8.54) N=4
3	8.75 (1.71) N=4	13.33 (4.16) N=3	11.25 (3.95) N=4	12.00 (5.20) N=3	10.33 (2.89) N=3	15.25 (9.29) N=4
4	15.67 (4.16) N=3	10.50 (6.36) N=2	17.33 (7.23) N=3	13.00 (3.46) N=3	14.00 (7.00) N=3	16.00 (7.39) N=4
5	7.75 (2.50) N=4	15.67 (0.58) N=3	12.50 (3.5[illegible]) N=2	12.67 (4.16) N=3	14.25 (6.55) N=4	16.00 (7.53) N=4
6	9.00 (0.00) N=1	18.50 (9.19) N=2	13.00 (2.83) N=2	27.00 (0.00) N=1	20.00 (0.00) N=1	10.00 (0.00) N=1

Note.-Standard deviations are given in parentheses.

TABLE 17

Number of Subjects and Combined Mean of Total Scores on Test Q for Treatment Groups 10-15 and for School

Treatment Group[a]					
10 (DD)	11 (DE)	12 (ED)	13 (EE)	14 (D)	15 (E)
12.19	15.50	13.79	17.28	14.21	14.68
N=15	N=15	N=15	N=16	N=17	N=20
School					
1	2	3	4	5	6
16.06	15.97	11.82	14.42	13.14	16.25
N=12	N=19	N=21	N=18	N=20	N=8

[a]Treatment means were obtained by averaging school means within each treatment, giving equal weight to each school and thus removing the effect of unequal numbers of students within each school.

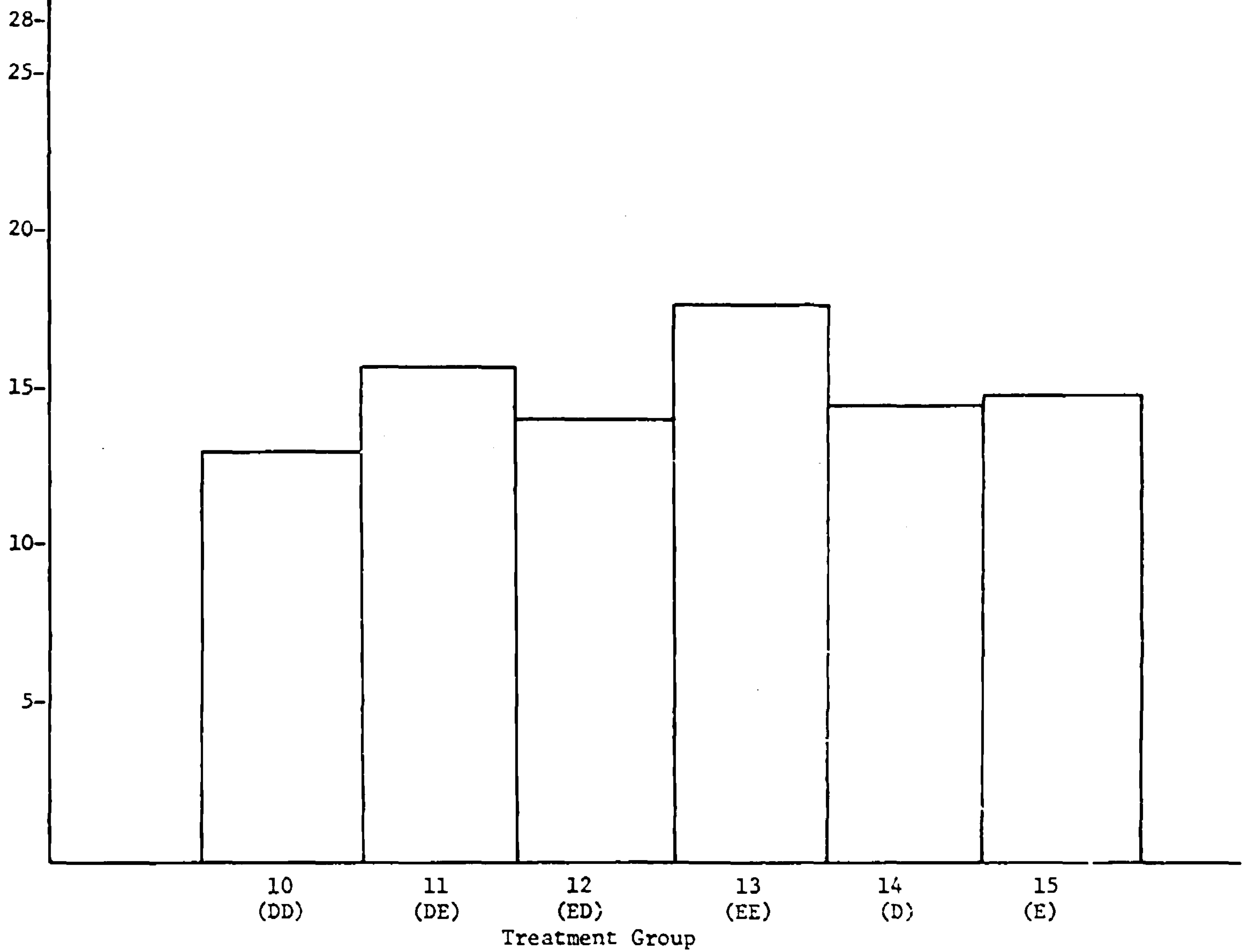

Fig. 4. Mean scores for Groups 10-15.

TABLE 18

Univariate Analysis of Covariance for Effects of Transfer Lessons on scores on Test Q.

Source	df	MS	F ratio	Probability
Schools	5	61.18	2.92	p<.05
Covariates	3	487.18	23.23	p<.0001
Schools X Treatments	24	10.05	0.48	p<.95
Covariate X Treatments	15	17.97	0.86	p<.75
X DE X Interference	3	13.88	0.66	p<.75
X DE X Transfer	3	29.49	1.41	p<.5
X DE	3	9.68	0.46	p<.75
X Interference	3	14.73	0.70	p<.25
X Transfer	3	22.07	1.05	p<.5
Treatments				
DE X Interference	1	18.14	0.86	p<.5
DE X Transfer	1	20.47	0.98	p<.5
D vs. E	1	38.71	1.85	p<.25
Interference	1	12.26	0.58	p<.5
Transfer	1	2.67	0.13	p<.72
Error (Residual)	44	20.97		

Chapter 6

DISCUSSION & CONCLUSIONS

Discussion

These experiments were performed to determine the differential effects on immediate acquisition, retention, and transfer, of two methods of presenting geometry concepts to s[illegible]h graders. The findings of the experiments indicated that Ss given the material under either method of presentation performed b[illegible]tter on a Test of Geometry Knowledge (Test Q) than Ss who were not given the material. Results showed, in addition, that method of presentation did not differentially affect either immediate acquisition or transfer, but did differentially affect retention of the material.

This lack of effect of method on immediate acquisition or on transfer would seem to be at odds with some of the findings cited in the literature. It has been found on several studies (see Chapter 3) that presenting material in an expository fashion enhances immediate acquisition. It should be noted that in this study an effort was made to equalize degree of original learning so that retention differences would not be attributable to differences in initial acquisition. Therefore, in compiling the lessons, number of examples, ratio of positive and negative instances, and sequence of examples was identical. An attempt was made to equalize the set of Ss under each condition towards the final test by giving Ss under both conditions and identical embedded test consisting of items parallel

to those in Test Q. In spite of this, it can be observed that the expository group attained a slightly higher mean score. The differences, however, were not significant.

Results of the transfer study are somewhat more puzzling. In view of the fact that positive transfer was found to be the only significant effect on the pilot study it was somewhat surprising to find no effect on the main study. The transfer experiment in the main study was different in three ways from the transfer experiment in the pilot study. In the pilot study Test 2, which was the test used to measure transfer, was a production test, while in the main study the test used to measure transfer, Test Q, was a recognition test. Changing the form of the test probably had its effect especially on the discovery group. In the main study the expository group showed evidence of positive transfer although it was not significant while the discovery group showed a tendency towards negative transfer although again the transfer was not significant. It could be held that the discovery group was more predisposed by the lesson material towards a production than a recognition test and that type of test would interact with treatment. There is no evidence pro or con in the data of the present study but an experiment is proposed in which the same lessons and different combinations of Test E and Test Q are used to measure the dependent variable. This would test the hypothesized interaction between method of presentation and type of test.

A second difference between pilot and main study lay in the point at which the transfer test was made. In the pilot study the test was given 24 hours after completion of the last lesson, while in the main study, the test for transfer was given immediately after completion of the last

lesson. It could be held that part of the transfer effect in the pilot study was a retention effect. This is suggested by the fact that there were no differences between the groups on the embedded test in pilot study. Of course the pilot study embedded test (Test 1) was a multiple choice test and the question of interaction between presentation method and test again arises. A second experiment could be preposed here in which the lessons remain the same across groups but transfer is measured at various intervals to determine interaction effects of transfer and retention interval.

The third difference between pilot and main study was in the lesson material itself. In the pilot study the triangle lesson and quadrilateral lessons were the same in number of concepts and number of examples per concept. In the main study there were less concepts introduced in the quadrilateral lesson (4) than in the triangle lesson (6) and there were more examples (12) in the quadrilateral than in the triangle lesson (6). The effect of the greater number of examples and fewer concepts may have been powerful enough on a test administered immediately to overshadow any effects of the triangle lesson.

Evidence for this conclusion is the fact that every group which had a quadrilateral lesson in the expository mode performed slightly better than any group which had a quadrilateral lesson in the discovery mode, regardless of whether the prior lesson was in the discovery or expository mode, or in fact whether or not there was a prior lesson. (see Figure 4).

The outcome of the retention experiment in this study is, of course, of greatest educational and psychological interest. The scores of the groups receiving lessons in the expository mode decreased as retention

interval increased, in the manner that classical forgetting theory would suggest. The scores of the discovery group, however, not only did not decrease, but actually increased over time. This interaction remained significant when the effects of school, IQ, arithmetic ability and performance on Test E had been removed from the model, and appears therefore to be attributable solely to method of presentation. It is impossible to explain this effect in terms of current theorty regarding memory and forgetting.

Two alternative explanations are possible. It could be held that the discovery method gave the student a set toward the concepts such that in interactions with other materials during the retention interval, he learned more about quadrilaterals and thus performed better on a test given after 21 days than on a test given after one day. This explanation is plausible and is the one which would probably be favored by Kersh (1958), who concluded that the motivation induced by the discovery method was more important than the understanding.

Another explanation for the effect derives from reminiscence and consolidation theory, although even reminiscence theory must be stretched to handle this data. Discovery learning could be interpreted as leading to what Berlyne (1964) describes as "a state of conflict. . . of such a kind that additional information e.g. specification of some hidden attribute of an object, identification of some impending event, will relieve it [p.11]." Berlyne concludes:

> If this is so, the subject is beset by what both common language and the technical language of information theory call "uncertainty." It is likely that prior learning will make him resort to

> exploratory activity to gain access to the information whose lack is being felt. If so the subject will be in the kind of state of heightened drive or arousal that we call "perceptual curiosity." [p.11].

The discovery mode of presentation, then, may be taken to produce arousal. Walker (1958) has proposed a learning and retention theory which would predict that high arousal during learning makes the trace learned less available for immediate recall but would result in greater permanent retention. Farley (1968) reviews a number of studies supporting this prediction. Kleinsmith and Kaplan (1963) compared recall of paired associates learned under high and low arousal and found that "paired associates learned under low arousal exhibited high immediate recall value and rapid forgetting. High arousal paired associates exhibited a marked reminiscence effect, that is, low immediate recall and high permanent memory [p.190]".

Kleinsmith and Kaplan (1964) and Walker and Tarte (1963) have successfully replicated this result. Their explanation is that

> The poor immediate recall for high arousal learning is predictable on the basis of the relative unavailability of actively consolidating neural traces. On the other hand the greater consolidation of high arousal learning also results in stronger permanent memory [Kleinsmith, Kaplan, & Tarte, 1963, p. 393].

The retention intervals in the Kleinsmith and Kaplan and the Walker and Tarte studies were 20 minutes, 45 minutes, 1 day and 1 week. The predicted effects did not appear in the present study until three weeks later. This might be explained in terms of the com-

plexity of the task. There is some evidence from the consolidation studies with animals that there is a functional relationship between task difficulty and consolidation time (Farley, 1968). Similar findings have been reported by Manske and Farley (1970) using children, and Lovejoy and Farley (1969) using adults on a paired associate learning task. Further evidence for this phenomenon is noted in several studies of individual differences using a paired associate task with children (Farley and Gilbert, 1970), and with adults (Osborne and Farley, 1970); a task involving verbal and motor skills (Farley, 1969a); and a task consisting of free recall of word lists (Farley, 1969b).

Data from the present study do not, however, permit choosing between these alternate explanations. In summary, the present study is difficult to interpret within the framework of classical theories of memory and forgetting but can, with some inferential leaps, be explained by alternate theories.

Psychological theories aside, the study has a number of important educational implications. In concordance with Worthen's findings and prior results of research on discovery and expository learning it gives greater weight to the contention that when the material being taught must be available for long term recall, involvement of the student in procuring answers for himself is preferable. Beyond this, the present study indicates that it is possible to get this involvement by means of written materials alone, such as textbooks, programmed booklets, etc.

Conclusions

The main conclusion of the present study is that method of presentation (expository vs. discovery) did differentially affect retention of the material presented. Expository learning was superior on short-term retention, measured immediately and one day later, but discovery learning was superior on longer-term retention, measured 21 days later. Method of presentation did not differentially affect transfer, although this may have been due to the fact that the transfer lesson was less powerful than the following lesson.

A second conclusion of some importance is that materials can be prepared in purely written form which can produce and assess these effects. These materials can also be described in specific detail in terms of a large number of variables which can be held constant or varied systematically. This opens the way for a series of further experiments whose effects will be more easily and more legitimately compared than some which have already appeared in the literature.[1]

Finally, it is this author's conclusion that the type of question asked and phenomenon investigated in this study may be answered and examined without recourse to explanation in terms of discovery, especially when these terms are used without the precision necessary for scientific investigation. Data may be collected and generalizations made on the basis of these observations. What Nagel (1961) has described as experimental laws (cf., Chapter 2) can be formulated

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[1] Herbert J. Klausmeier and Dorothy A. Frayer of the Wisconsin Research and Development Center started this line of development and investigation. The present study as was Frayer's study (1969) is a beginning validation of this approach.

and their findings reported and used without the necessity of having the phenomena explained.

Other kinds of questions will eventually have to be asked and these questions will necessitate the formulation of what Nagel (1961) called a "theory" (cf., Chapter 2). This theory when it is formulated should be based not on some hasty generalizations, but on a strong epistemological examination of the phenomena under investigation as well as on systematically recorded observations. Perhaps more order can then be brought into the untidy field now included under the rubric "discovery learning."

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Appendix A

Raw Data

Scores on Test Q

Scores on Test E

IQ Scores

Math Ability Scores

School 1 Class 1

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
24.	1	123	7.6	15	27
26.	5	111	6.3	18	27
27.	14	108	6.9	12	11
28.	5	117	7.0	5	23
31.	2	102	5.3	8	4
32.	6	108	5.7	11	20
34.	9	110	7.0	11	C*
36.	8	99	5.1	6	C
38.	14	96	5.5	11	11
39.	7	91	5.5	5	C
40.	3	118	7.8	25	24
41.	9	116	7.6	14	C
42.	4	124	8.1	22	23
45.	15	104	5.9	15	21
46.	15	99	6.1	9	20

*Note - C indicates that S was in the control group and therefore did not have an embedded test in the lessons.

School 1 Class 2

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
1.	8	90	5.3	13	0
3.	10	127	9.1	22	23
4.	11	118	6.4	15	19
5.	11	110	7.5	17	24
6.	4	102	7.5	13	18
7.	13	131	6.9	27	27
8.	14	113	7.3	19	20
9.	13	93	5.5	11	12
10.	12	118	6.7	14	14
11.	6			7	16
12.	2	125	8.1	12	22
14.	3	127	8.2	17	21
15.	9	127	8.9	15	0
17.	8	122	7.9	9	0
18.	1	112	7.1	15	6
19.	15	100	5.8	10	7
20.	3	113	6.8	13	18
22.	7	122	7.6	9	0
23.	7	115	8.9	15	0

School 2 Class 1

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
30.	6	139	8.9	27	28
31.	15	123	7.9	8	20
32.	10	85	4.7	5	7
33	13	122	7.1	18	26
34.	11	111	6.6	15	17
35.	12	117	8.0	21	20
36.	10	138	6.7	15	23
37.	8	120	6.9	14	C
39.	2	88	5.3	6	11
40.	11	134	7.5	19	17
41.	2	137	7.7	20	24
42.	9	128	7.2	18	C
44.	1	111	6.5	11	17
45.	11	111	6.9	23	23
46.	5	106	5.3	7	11
47.	15	124	7.9	26	27
48.	15	122	7.8	26	23
50.	4	102	4.8	12	15
51.	14	102	4.8	9	12
53.	12	97	4.0	15	17
54.	9	108	7.2	9	C
55.	13	97	5.5	21	14

School 2 Class 1

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
56.	3	117	7.3	25	27
57.	7	101	4.7	6	

School 2 Class 2

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
1.	4	118	8.1	21	26
2.	3	121	8.1	26	20
4.	13	132	7.8	26	28
5.	14	104	7.5	17	14
6.	7	108	7.3	22	C
7.	5	120	7.1	18	21
8.	9	111	6.5	18	C
9.	2	138	8.2	15	23
10.	7	92	5.4	16	C
11.	12			8	12
12.	5	111	7.1	18	24
13.	9	122	8.3	17	C
14.	6	105	7.2	24	27
15.	8	118	7.6	12	C
16.	3	80	5.7	18	6
17.	7	111	7.2	11	C
18.	5	103	5.7	12	27
21.	15	113	6.1	18	20
22.	3	108	5.8	11	12
23.	13	102	6.6	15	20
24.	1	117	7.3	18	17
25.	4	119	8.1	24	22

School 2 Class 2

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
26.	4	135	8.4	20	26
27.	1	109	6.8	7	17
28.	2	110	5.7	10	4
29.	14	114	7.4	12	17

School 3 Class 1

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
1.	12	87	4.9	8	3
2.	3	107	5.7	10	5
3.	6	130	7.0	14	20
4.	11	108	5.9	12	17
6.	3	115	6.8	13	15
7.	11	125	6.8	18	22
8.	14	76	4.6	12	4
9.	13	114	4.6	9	12
10.	13	104	4.8	18	17
11.	6	115	6.5	13	22
12.	5	96	5.7	8	6
13.	9	120	6.7	17	[illegible]
14.	4	109	5.0	8	18
15.	1	109	5.6	13	3
16.	15	115	5.0	10	11
17.	4	88	4.7	6	5
18.	10	126	6.2	11	13
19.	15	132	7.0	27	22
20.	8	125	7.3	13	[illegible]
21.	14	104	4.4	12	9
22.	9	117	6.6	16	[illegible]
[illegible]3.	1	114	7.7	8	12

School 3 Class 1

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
24.	3	123	5.4	8	19
25.	6	104	5.3	8	19
26.	2	129	5.9	15	5
27.	4	104	4.1	11	16
28.	15	124	6.7	18	23
29.	13	117	6.6	9	19
30.	8	101	4.3	12	C
31.	8	98	6.5	7	C
32.	9	122	6.1	9	C
33.	8	100	4.9	7	C
34.	14	129	5.5	7	7

School 3 Class 2

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
38.	10	100	4.9	7	6
39.	12	88	4.4	8	6
40.	5	99	5.2	9	4
42.	6	87	5.0	5	3
44.	3	99	4.9	14	3
45.	10	111	5.5	9	5
46.	2			8	8
47.	5	129	7.0	10	18
48.	1	80	4.2	8	6
50.	7	114	7.0	8	0
51.	12	129	5.6	13	4
52.	10	111	5.2	8	4
53.	2	129	7.5	13	14
54.	15	107	4.9	6	9
55.	7	91	4.3	6	0
56.	7	134	7.5	7	0
57.	11	118	7.6	10	20
58.	5	81	5.2	7	4
60.	1	103	6.3	11	14
61.	4	134	7.5	16	21
62.	4	126	6.1	10	17
63.	9	108	5.5	9	0

School 3   Class 2

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
64.	12	121	6.9	16	13
65.	2	112	6.2	14	24

School 4   Class 1

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
28.	5	94	4.5	15	15
30.	13	80	4.4	11	5
31.	12	98	4.9	9	12
32.	13	109	6.8	17	18
33.	7	102	5.9	8	[illegible]
34.	14	88	4.6	6	8
35.	6	102	5.1	10	14
37.	1	105	5.9	10	17
38.	9	105	5.2	5	[illegible]
39.	12	137	7.9	21	22
40.	3	140	9.2	25	23
41.	6	99	6.0	17	21
42.	2	90	6.3	6	14
43.	15	88	5.2	13	19
44.	14	104	6.9	17	14
45.	8	115	5.5	5	[illegible]
46.	1	119	7.5	15	19
47.	2	114	6.5	9	14
48.	11	123	5.6	15	18
49.	10	108	6.7	19	21
50.	15	101	5.7	11	21
51.	15	108	6.5	13	21

School 4 Class 1

Student No.	Treatment No.	IQ	Iowa Math Score	Fianl Test Score	Embedded Test Score
52.	4	91	3.8	6	9
53.	8	99	6.0	14	C
54.	3	115	6.8	16	19
55.	3	106	6.8	21	23

School 4 Class 2

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
1.	12	121	6.7	22	24
2.	6	103	5.1	7	15
3.	11	97	4.2	6	19
4.	1	143	7.3	12	26
5.	9	111	5.9	10	C
6.	4	132	8.2	25	20
7.	6	105	4.8	6	C
8.	15	116	7.1	27	24
9.	14	114	7.1	19	17
10.	10	114	7.2	17	16
11.	8	83	5.7	4	C
12.	13	116	6.7	11	19
13.	1	114	6.2	13	14
14.	5	113	5.9	17	22
15.	6	114	7.0	10	22
16.	4	113	5.3	11	24
17.	2	126	7.5	13	21
19.	5	112	7.7	12	18
20.	2	83	4.0	11	11
21.	10	98	6.5	11	20
22.	9	135	7.6	10	C
23.	7	122	6.0	11	C

School 4 Class 2

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
24.	7	102	6.0	5	C
25.	7	121	6.8	6	C
26.	5	150	9.1	28	27
27.	9	115	6.2	9	C

School 5 Class 1

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
3.	11	101	5.0	16	19
4.	8	90	4.6	7	C
5.	3	101	6.4	6	8
6.	14	104	6.5	24	22
8.	10	79	3.7	8	2
9.	15	120	7.7	27	25
10.	14	100	5.2	12	23
11.	12	112	4.9	10	21
12.	6	117	8.2	11	25
13.	14	104	5.4	10	8
14.	6	103	6.9	9	14
15.	2	107	6.1	6	12
16.	15	97	4.2	14	14
17.	8	106	5.4	9	C
18.	3	86	5.4	5	6
20.	13	98	5.8	14	18
21.	1	136	8.5	21	25
23.	4	110	6.1	20	22
24.	14	83	5.1	11	5
26.	4	116	5.2	19	18
28.	5	102	6.3	24	17

School 5 Class 2

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
29.	3	86	5.5	11	9
30.	2	104	5.6	11	5
31.	10	109	6.1	5	11
32.	11	86	5.1	16	12
34.	2	135	8.9	11	24
35.	9	132	8.9	12	C
36.	1	98	4.5	8	4
37.	7	85	4.5	11	C
38.	10	103	4.3	7	2
39.	9	93	5.4	5	C
41.	8	89	5.0	6	C
42.	13	115	7.4	16	19
43.	2	98	4.9	10	7
44.	7	99	4.8	5	C
45.	13	85	4.5	8	16
46.	5	129	8.4	19	22
47.	12	101	4.6	15	6
48.	5	114	6.6	22	26
49.	7	105	5.2	10	C
51.	15	81	3.8	10	19
52.	7	127	5.7	9	C
53.	6	108	4.9	11	17

School 6 Class 1

Student No.	Treatment No.	IQ	Iowa Math Score	Final Test Score	Embedded Test Score
54.	11	105	6.1	15	18
55.	10	133	6.8	11	20
56.	15	117	7.1	13	24
2.	3	123	5.9	15	17
3.	11	116	7.1	25	25
7.	8	112	5.5	8	6
8.	15	93	4.7	10	11
9.	10	104	5.3	9	5
12.	4	108	6.6	12	15
13.	12	129	6.5	15	16
14.	14	121	7.1	20	25
16.	12	116	6.0	11	15
17.	7	145	7.2	10	6
18.	6	114	7.3	19	21
19.	8	83	6.0	6	6
20.	3	101	5.6	7	10
21.	11	106	5.9	12	16
24.	1	144	8.2	12	24
25.	13	127	7.3	27	28
26.	2	87	3.6	6	7

Appendix B

Instructions

to Proctors and Ss

General Instruction to Proctor

1. All material is packaged by school and class and each booklet has a student's name. On arrival at the school it is only necessary to open the pack, distribute it to the students, pass out pencil, ruler, and cardboard strip to the students; read the instructions and let them go.

2. Indicate your willingness to help them to interpret any words or questions but not to give them answers.

3. If there should be a new child in the class (one not on the list I received) have him work on material specified by regular teacher.

4. Ask regular teacher to specify what those children finishing early might do.

5. In case of interruption of the class (by fire drill or some such) just ask them to leave the materials on the desk and they may start [illegible] in when they return. -Note the amount of time lost- so that it may be subtracted from the times indicated on the front of the booklet.

6. No special pencils are needed except for the tests. Then everyone should have a number 2 pencil.

7. If you should have to leave ask the regular teacher to collect the material as each student finishes.

Day 1 Instructions

Good Morning (Afternoon)

My Name is ________________. I am working with some Educational Psychologists at the University of Wisconsin in Madison. These psychologists are trying to find out how to make it easier for children to learn mathematics. They have written some lessons and each day this week you will study one of these lessons. After you have completed the lessons, you will be given a test to see how much you learned. Please do the best job you can on both the lessons and the tests. If you do you will learn some geometry and more than that you will help us and other psychologists find ways to make learning easier for other boys and girls.

I am going to hand out the first lesson now. Do not open it until I tell you to do so. (Distribute the lessons, pencils, rulers & strips.) Now does everyone have a lesson, pencil, ruler and cardboard strip? OK! There are a number of different kinds of lessons so do not worry if yours does not look like your neighbor's.

Check your name and write the name of the school on the first page, (the cover). Turn to the page where it says Word List. If you do not have such a page just start your work on the first page and complete the answers right through the booklet. The word list reads: (Read the heading, pronounce each work and have the children repeat it. Ask if they can pronounce each word - any questions.)

(Hold up copy of Lesson 1)

This lesson may be different for other lessons you have done. Here is how it works. The pages in your lesson will look like this: (Open any page after word list) This side (point) has questions for you to answer. The other side (point) has the correct answer.

When you do the lesson you should cover the answers with the piece of cardboard like this. (Show them).

After you write your answer, to the questions move the cardboard down just far enough so that you can see if the answer you wrote is correct. If it is go on to the next question. Let's do the first page together. (Go thru first page of questions) Remind them to move the strip and read the correct answer.

If you make a mistake and find that the answer you wrote down is not right just draw a line thru it and write the correct answer beside it.

(Do Question 1 on the Board Correcting an Error)

By making corrections like this we will know which questions are too hard.

Does anyone have a question? Go through the rest of the lesson by yourselves now. If you have any questions or come to any words that you do not know, raise your hand and I will help you.

Write the exact time that it is <u>now</u> (Tell them) on the front cover where it says "starting time."

When you finish write the exact time where it says "finishing time."

Take your time, so you will understand and be able to answer questions later - go ahead.

Day 2 Instructions

Good Morning --

Today's lesson is just like yesterday's. You know how to use the cardboards so please check your name, fill in the name of the school, date and class. Now turn to the page which says "Word List". Those who do not have such a page may start work.

[Go Through the Word List]

Now continue with the lesson. Put the time it is now on the cover where it says "starting time." When you finish be sure to put the time you finish on the front cover.

Remember if you have any questions just raise your hand and I will help you.

Go ahead.

Day 3 - Instructions

Good Morning

Please check your names, and write in the name of the school, grade and date on the third lesson, which we are going to do today. Today there are several different kind of lessons. Some of you have one kind, some have another. Those boys and girls who have no word list in their lesson may write down the starting time and start working. Those boys and girls who have Lesson III will have this word list.

[Read -d List on Lesson III]

Now those boys and girls who have Lesson IV will have this word list.

[Read Word List on Lesson IV]

You will not need your cardboard on every page today as answers are not given on every page. When you come to a page which has a line down the side like this

[Show them]

Use the cardboard strips as you did in the other lessons.
Go ahead. If you have any questions raise your hand. The Starting time is _________. Remember to write the Finishing time on the lesson when you get done.

Day 4 - Instructions

Good Morning --

Today's lesson is the fourth lesson and for some of you it is the last lesson. Some of you will also get a test today so don't be surprised. I want to say again that you should not be worried about the test. Just do your best.

The lesson today is very much like yesterday's. When you come to a page which has a line down the side and which has the answers, just cover the answers with your cardboard and continue as you have been doing.

Now let us go through the word list

[Go through the word list]

Remember when you use your ruler to measure in inches. Write the name of the school etc. on the front cover, and the starting time which is __________. And if you have any questions, just raise your hand.

Day 5 Instructions

Good Morning --

Today many of you will get a test. Some of you will get a lesson, followed by a test. Some of you will be tested at another time. We will go through the procedure for doing the test. You will have a test booklet which has the questions and a sheet like this [show them] on which you put your answers. On the test booklet check your name and write the name of the school, grade etc. On the answer sheet write your name, date and under the word "course" put the school name, and your teacher's name under "instructor." Do not fill in anything above your name on the sheet. Let us go through the front cover of the test. [Read] [Tell them they have the special pencil #2] [Do the example.] Now those of you who have a lesson, look at the word list.[Go through the word list.]
Your lesson is like the past two you have had. When you come to the page with the answers, cover the answers with your cardboard as you have been doing. Remember to use inches when you measure with your ruler. Fill in the front cover. The starting time is ______________.

Those who have neither a test or a lesson will have an assignment from your teacher.

Go to work.

Test Instructions

(For 11 and 21 Day Tests)

Hello

We are back to test some more boys and girls in order to find out how much you remember from the lessons you did. Those of you who have a test today should also have an answer sheet like this [Show them] inside the test booklet, and you should also have a special pencil with a No. 2 on the end near the eraser, and a ruler. The test booklet has the questions and you should put your answers on the answer sheet.

Check your name on the booklet, then write the name of the school, your grade and the date on the cover. On the answer sheet, write your name, the date. Under the word "course" put the name of the school, and under "instructor" write your teacher's name. Do not fill in anything above your name on the sheet. Let us go through the instructions on the front cover of the test.

[Read the Instructions and Do the Examples]

Any questions? Go ahead.

Appendix C

Sample of

Lesson Material

Lesson on the Concept

PARALLELOGRAM

Presented in the

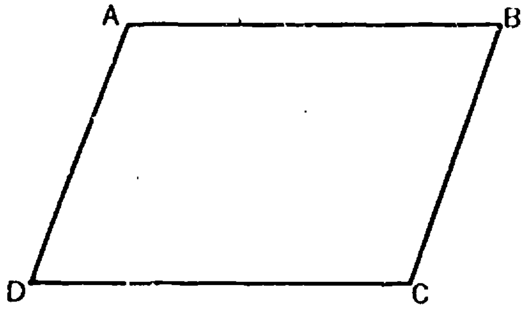
Expository Mode

Hello,

Yesterday you learned how to tell whether or not a figure is a quadrilateral. You learned that any figure which has four and only four sides is called a quadrilateral. You also learned how to tell whether or not a quadrilateral is a rhombus. You learned that a quadrilateral which has four sides all equal in length is called a rhombus. Today you will learn about two more special kinds of quadrilaterals, parallelograms and trapezoids.

Remember that when learning about these figures you need only look at the sides. Find out if they are the same length or not and whether they are parallel or not. You do not have to think about anything else like whether the figure is big or small, or thin or fat, or straight or turned around. Just think about the <u>sides</u>. You will learn about the figures.

1. The next special kind of quadrilateral we will study is called a parallelogram. This figure <u>is</u> a parallelogram. A parallelogram has two pairs of parallel sides. Look carefully at the following figures and see how they are alike and how they are different.



If you use your ruler you will find that sides AB and DC are parallel. You will also find that sides AD and BC are parallel. Opposite sides of a parallelogram are also equal in length. The measures of the line segments in this figure are given below. Use your ruler if you wish to check them.

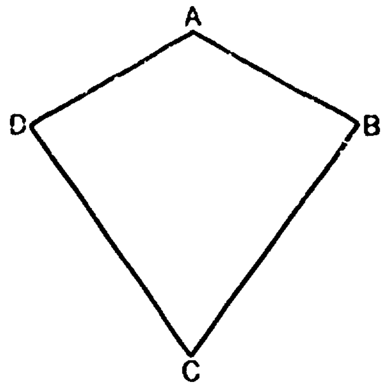
$\overline{AB}$ is 2 inches long.

$\overline{DC}$ is 2 inches long.

$\overline{AD}$ is 1-1/2 inches long.

$\overline{BC}$ is 1-1/2 inches long.

2. Look at this figure.



This is not a parallelogram. It does not have 2 pairs of parallel sides. $\overline{AB}$ is not parallel to $\overline{DC}$ and $\overline{AD}$ is not parallel to $\overline{BC}$. Opposite sides are not equal. Check the measures below.

$\overline{AD}$ is 1 inch long.

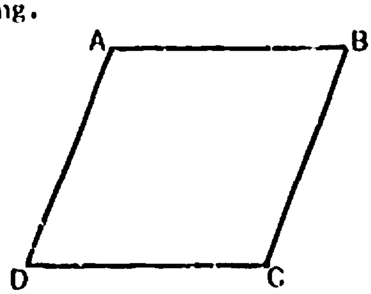
$\overline{AB}$ is 1 inch long.

$\overline{CB}$ is 1-1/2 inches long.

$\overline{CD}$ is 1-1/2 inches long.

$\overline{AB} \neq DC$; $\overline{AD} \neq BC$. ($\neq$ means not equal to)

3. Now look at this drawing.



This is a parallelogram. It has two pairs of parallel sides. $\overline{AB}$ is parallel to $\overline{DC}$ and $\overline{AD}$ is parallel to $\overline{BC}$. Check with your ruler if you wish. Opposite sides are also equal. The measures of the sides are given below. Check them if you wish.

$\overline{AB}$ is 1-1/4 inches long.

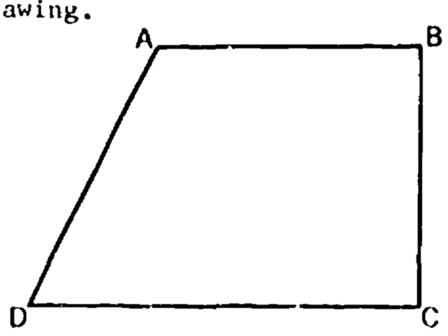
$\overline{DC}$ is 1-1/4 inches long.

$\overline{AD}$ is 1-1/4 inches long.

$\overline{BC}$ is 1-1/4 inches long.

$\overline{AB} = \overline{DC}$ and $\overline{AD} = \overline{BC}$.

4. Here is another drawing.



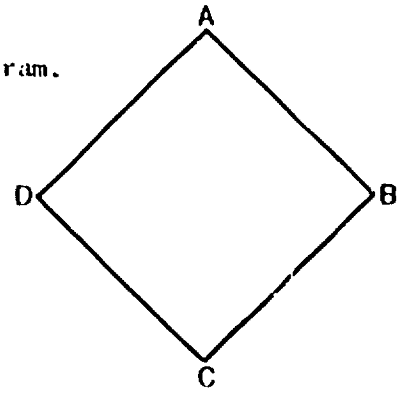
This is not a parallelogram. It does not have two pairs of parallel sides. You will notice that you have one pair of parallel sides but not two pairs.

$\overline{AB}$ and $\overline{CD}$ are parallel.

$\overline{AD}$ and $\overline{BC}$ are not parallel.

Notice also that $\overline{AD}$ is longer than $\overline{BC}$.

5. This figure is a parallelogram.



Look at these measures of the sides and you will see.

$\overline{AB}$ is 1-1/4 inches long.

$\overline{DC}$ is 1-1/4 inches long.

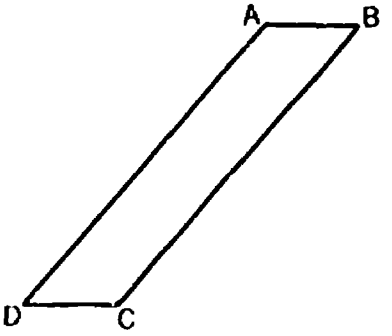
$\overline{CB}$ is 1-1/4 inches long.

$\overline{AD}$ is 1-1/4 inches long.

Notice that $\overline{AB} = \overline{DC}$ and $\overline{CB} = \overline{AD}$.

This figure must also have two pairs of parallel sides. If you use your ruler to check you will also find that $\overline{AB}$ is parallel to $\overline{DC}$ and $\overline{CB}$ is parallel to $\overline{AD}$.

6. And this is a parallelogram. It has two pairs of parallel sides. Opposite sides are also equal.



Check the measures of the sides written below.

$\overline{AB}$ is 1/2 inch long.

$\overline{DC}$ is 1/2 inch long.

$\overline{CB}$ is 2 inches long.

$\overline{AD}$ is 2 inches long.

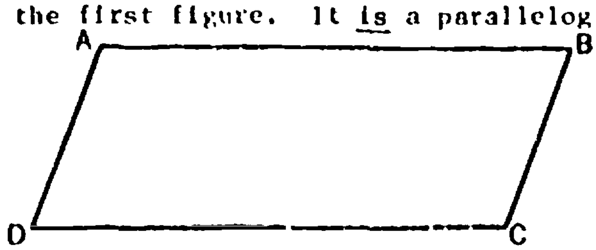
If you use your ruler you will also find that $\overline{AB}$ is parallel to $\overline{DC}$ and $\overline{AD}$ is parallel to $\overline{BC}$. You know that all the figures in questions 1, 2, 3, 4, 5, and 6 are quadrilaterals. There are two ways you can tell whether or not they are parallelograms.

1. If there are two pairs of parallel sides; or

2. If opposite sides are equal in length.

13. The first six figures you studied (questions 1 to 6) were to help you learn how to tell whether or not a figure was a parallelogram. In case you are not sure, we are going to look at six more figures. These should help you know for sure whether or not a figure is a parallelogram. First, we must be sure you can remember the word parallelogram itself. Repeat it a couple of times to yourself: parallelogram, parallelogram, parallelogram. Now write the word parallelogram here. ________________________ Remember what we said at the beginning of the lesson about describing a figure in terms of its sides and nothing else. Look again carefully at the next six figures. Notice which are alike and how they are alike.

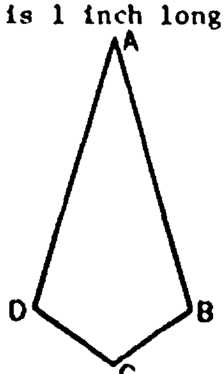
14. Here is the first figure. It is a parallelogram.



If you use your ruler you will find that sides AB and DC are parallel. You will also find that sides AD and BC are parallel. Opposite sides of a parallelogram are also equal. The measures of the sides in this figure are given below. Use your ruler if you wish to check them.

$\overline{AB}$ is 2 1/2 inches long.
$\overline{DC}$ is 2 1/2 inches long
$\overline{AD}$ is 1 inch long.
$\overline{BC}$ is 1 inch long.

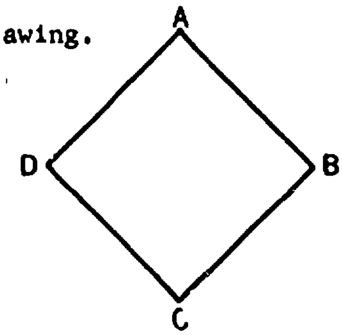
15. Look at this figure.



This is not a parallelogram. It does not have 2 pairs of parallel sides. $\overline{AB}$ is not parallel to $\overline{DC}$ and $\overline{AD}$ is not parallel to $\overline{BC}$. Opposite sides are not equal. Check the measures below.

$\overline{AB}$ is 1 1/2 inches long.
$\overline{DC}$ is 1/2 inch long.
$\overline{AD}$ is 1 1/2 inches long.
$\overline{BC}$ is 1/2 inch long.
$\overline{AB} \neq \overline{DC}$; $\overline{AD} \neq \overline{BC}$

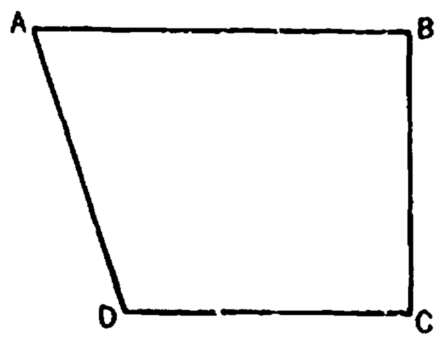
16. Now look at this drawing.



This is a parallelogram. It has two pairs of parallel sides. $\overline{AB}$ is parallel to $\overline{DC}$ and $\overline{AD}$ is parallel to $\overline{BC}$. Check with your ruler if you wish. Opposite sides are also equal. The measures of the sides are given below. Check them if you wish.

$\overline{AB}$ is 1 inch.
$\overline{DC}$ is 1 inch.
$\overline{AD}$ is 1 inch.
$\overline{BC}$ is 1 inch.

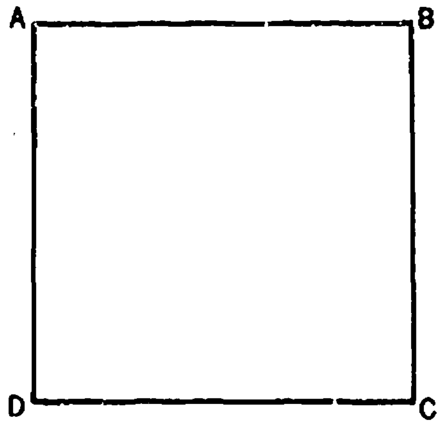
17. Here is another drawing.



This is not a parallelogram. It does not have two pairs of parallel sides. Notice that it has one pair of parallel sides but not two pairs.

$\overline{AB}$ is parallel to $\overline{DC}$.
$\overline{AD}$ is not parallel to $\overline{BC}$.

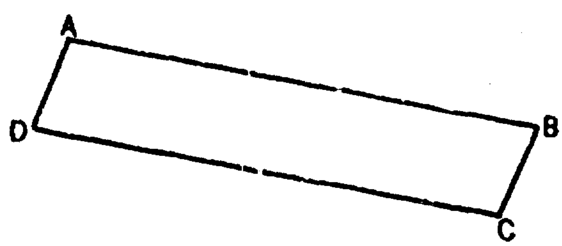
18. And now look at this figure.



This figure is a parallelogram. Look at these measures of the sides and you will see.

$\overline{AB}$ is 2 inches long.
$\overline{DC}$ is 2 inches long.
$\overline{AD}$ is 2 inches long.
$\overline{BC}$ is 2 inches long.

19. And this is a parallelogram. It has two pairs of parallel sides. Opposite sides are also equal.



Check the measures of the sides written below.

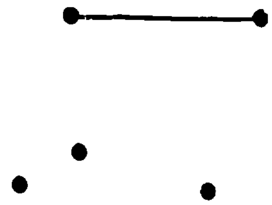
$\overline{AB}$ is 2 1/2 inches long.
$\overline{CD}$ is 2 1/2 inches long.
$\overline{AD}$ is 1/2 inch long.
$\overline{BC}$ is 1/2 inch long.

If you use your ruler you will also find that $\overline{AB}$ is parallel to $\overline{DC}$ and $\overline{AD}$ is parallel to $\overline{BC}$.

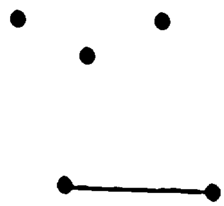
You know that the last six figures are all quadrilaterals. There are two ways you can tell whether or not they are parallelograms.

1. If there are two pairs of parallel sides; or
2. If opposite sides are equal in length.

20. Using a ruler, connect as many points as you need to finish the figure to make a quadrilateral that is <u>not</u> a parallelogram.



21. Using a ruler, connect as many points as you need to finish the figure so it is a <u>parallelogram</u>.



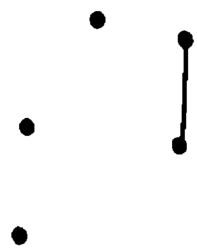
22. All parallelograms have something special that not all quadrilaterals have. Parallelograms have ________ pair(s) of ______________ sides.

____

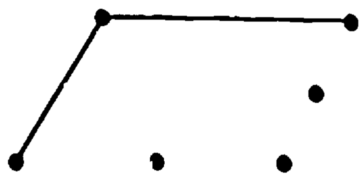
____

23. List all that is needed to completely describe <u>parallelogram</u>.

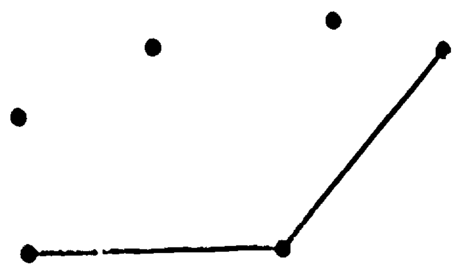
24. Using a ruler, connect as many points as needed to close the figure so it has 2 pairs of parallel sides.



25. Using a ruler, complete this figure so that it is a quadrilateral but <u>not</u> a parallelogram.



26. Using your ruler, complete this figure so that it <u>is</u> a parallelogram.



Lesson on the Concept

PARALLELOGRAM

Presented in the

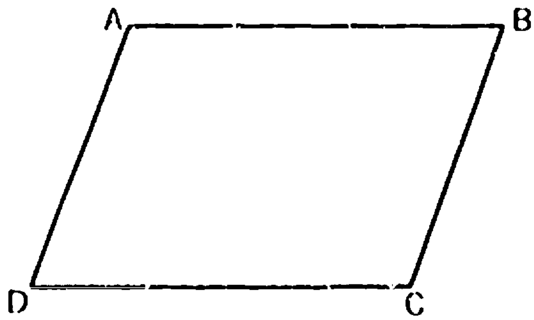
Discovery Mode

Hello,

Yesterday you learned how to tell whether or not a figure is a quadrilateral. You learned that any figure which has four and only four sides is called a quadrilateral. You also learned how to tell whether or not a quadrilateral is a rhombus. You learned that a quadrilateral which has all four sides equal in length is called a rhombus. Today you will learn about two more special kinds of quadrilaterals, parallelograms, and trapezoids.

Remember that when learning about these figures you need only look at the sides. Find out if they are the same length or not and if they are parallel or not. You do not have to think about anything else like whether it is big or small, or thin or fat, or straight or turned around. Just think about the sides. You will learn about the figures.

1. The next special kind of quadrilateral we will study is called a <u>parallelogram</u>. The next six problems will help you tell whether or not a figure is a parallelogram. Look at them carefully and notice how the figures are alike and how they are different. Here is the first figure.



Use your ruler to find out some things about sides AB and DC. Did you measure them? How long are they?

$\overline{AB}$ is __________ inches long.

$\overline{DC}$ is __________ inches long.

What else did you notice about $\overline{AB}$ and $\overline{DC}$? Check again and write what you find out here.______________________________

____

What about $\overline{AD}$ and $\overline{BC}$?

$\overline{AD}$ is __________ inches long.

$\overline{BC}$ is __________ inches long.

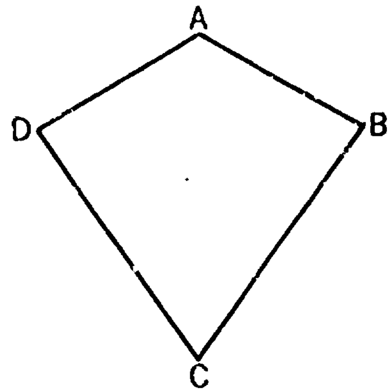
What else did you notice about $\overline{AD}$ and $\overline{BC}$? ____________________

____

Is $\overline{AD}$ parallel to $\overline{BC}$? ______________________________

Is $\overline{AB}$ parallel to $\overline{DC}$? ______________________________

2. Look at this figure.



Measure sides AB, AD, CB, and CD.

$\overline{AD}$ is ________ inches long.

$\overline{AB}$ is ________ inches long.

$\overline{CB}$ is ________ inches long.

$\overline{CD}$ is ________ inches long.

Is $\overline{AD}$ parallel to $\overline{BC}$? ______________________________

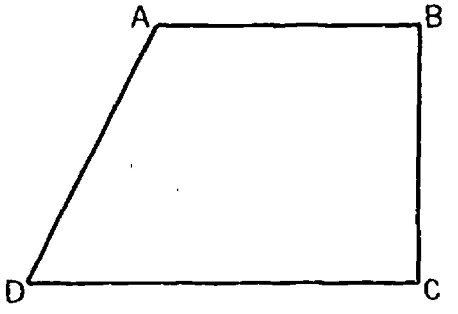
Is $\overline{AB}$ parallel to $\overline{DC}$? ______________________________

How is this figure different from the figure in the last question?

____

____

4. Here is another drawing.



Measure the sides.

$\overline{AB}$ is __________ inches long.

$\overline{CD}$ is __________ inches long.

$\overline{AD}$ is __________ inches long.

$\overline{BC}$ is __________ inches long.

Can you see how this is different from the figure in Question 3?

Use your ruler. Say how you think the figure in Question 3 is different from the figure in this question.

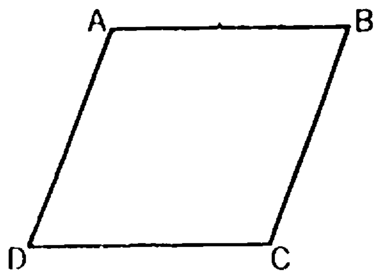
____

____

Is $\overline{AD}$ parallel to $\overline{BC}$? ______________________________

Is $\overline{AB}$ parallel to $\overline{DC}$? ______________________________

3. Now look at this drawing.



Measure the sides.

$\overline{AB}$ is __________ inches long.

$\overline{DC}$ is __________ inches long.

$\overline{AD}$ is __________ inches long.

$\overline{BC}$ is __________ inches long.

Is $\overline{AB}$ parallel to $\overline{DC}$? ______________________________________

Is $\overline{AD}$ parallel to $\overline{BC}$? ______________________________________

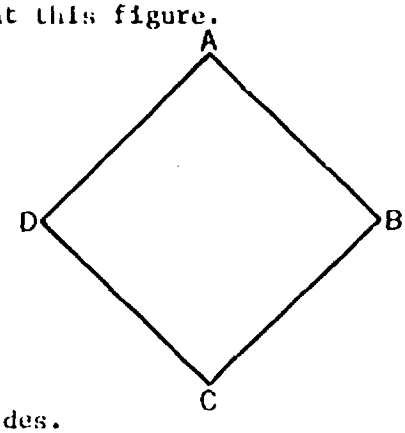
How is this different from the last figure? __________________

____

How is it like the figure in Question 1? ____________________

____

5. And now look at this figure.



Measure the sides.

$\overline{AB}$ is __________ inches long.

$\overline{AD}$ is __________ inches long.

$\overline{CB}$ is __________ inches long.

$\overline{CD}$ is __________ inches long.

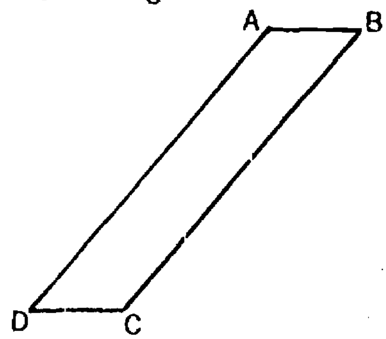
What else do you notice about the sides? ____________________

____

Is $\overline{AD}$ parallel to $\overline{BC}$? ____________________

Is $\overline{AB}$ parallel to $\overline{DC}$? ____________________

6. Here is another figure.



Write the lengths of the sides here.

$\overline{AB}$ is __________ inches long.

$\overline{DC}$ is __________ inches long.

$\overline{CB}$ is __________ inches long.

$\overline{DA}$ is __________ inches long.

Use your ruler and say what you note about sides AB and DC and AD and BC besides the lengths. ________________________

____

Is $\overline{AD}$ parallel to $\overline{BC}$? ____________________________________

Is $\overline{AB}$ parallel to $\overline{DC}$? ____________________________________

7. Of the last six figures, four were alike and two were different.

What are the numbers of the four which were alike?

____

8. Remember what we said at the beginning of the lesson about describing figures by saying something about sides. Say how you think that the four figures you named in the last question are alike.

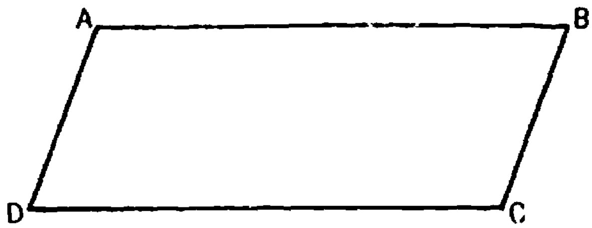
____

____

Each of the four figures which are alike is called a parallelogram.

17. The first six figures you studied (questions 1 to 6) were to help you learn how to tell whether or not a figure was a parallelogram. In case you are not sure, we are going to look at six more figures. These should help you know for sure whether or not a figure is a parallelogram. First, we must be sure you can remember the word parallelogram itself. Repeat it a couple of times to yourself: parallelogram, parallelogram, parallelogram. Now write the word parallelogram here. ______________________
Remember what we said at the beginning of the lesson about describing a figure in terms of its sides and nothing else. Look again carefully at the next six figures. Notice which are alike and how they are alike.

18. Here is the first figure.



Measure the sides AB and DC.

$\overline{AB}$ is ____________ inches long.

$\overline{DC}$ is ____________ inches long.

What else did you notice about $\overline{AB}$ and $\overline{DC}$? Check again and write what you find out here.

____

____

Measure sides AD and BC

$\overline{AD}$ is ____________ inches long.

$\overline{BC}$ is ____________ inches long.

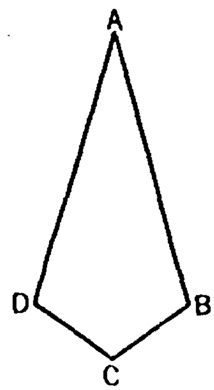
What else did you notice about $\overline{AD}$ and $\overline{BC}$? ______________

____

Is $\overline{AD}$ parallel to $\overline{BC}$? ________________________________

Is $\overline{AB}$ parallel to $\overline{DC}$? ________________________________

19. Look at this figure.



Measure the sides AB, AD, CB, and CD.

$\overline{AB}$ is __________ inches long.

$\overline{AD}$ is __________ inches long.

$\overline{CB}$ is __________ inches long.

$\overline{CD}$ is __________ inches long.

Is $\overline{AD}$ parallel to $\overline{BC}$? ________________________________

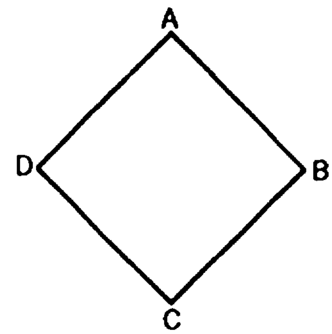
Is $\overline{AB}$ parallel to $\overline{DC}$? ________________________________

How is this figure different from the figure in the last question?

____

____

20. Now look at this drawing.



Measure the sides.

$\overline{AB}$ is ________ inches long.

$\overline{AD}$ is ________ inches long.

$\overline{BC}$ is ________ inches long.

$\overline{DC}$ is ________ inches long.

Is $\overline{AB}$ parallel to $\overline{DC}$? ______________________________

Is $\overline{AD}$ parallel to $\overline{BC}$? ______________________________

How is this figure different from the last figure? ________

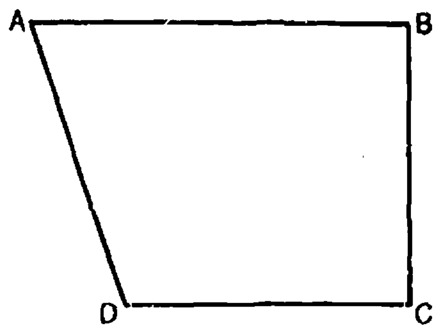
____

How is this figure like the figure in question 18? ________

____

____

21. Here is another drawing.



Measure the sides.

$\overline{AB}$ is __________ inches long.

$\overline{CD}$ is __________ inches long.

$\overline{AD}$ is __________ inches long.

$\overline{BC}$ is __________ inches long.

Can you see how this figure is different from the figure in question 20? Use your ruler. Say how you think the figure in question 20 is different from the figure in this question.

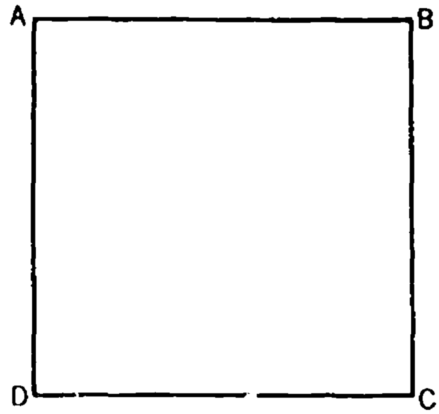
____

____

Is $\overline{AD}$ parallel to $\overline{BC}$? ________________________________

Is $\overline{AB}$ parallel to $\overline{DC}$? ________________________________

22. And now look at this figure.



Measure the sides.

$\overline{AB}$ is ________ inches long.

$\overline{CD}$ is ________ inches long.

$\overline{AD}$ is ________ inches long.

$\overline{BC}$ is ________ inches long.

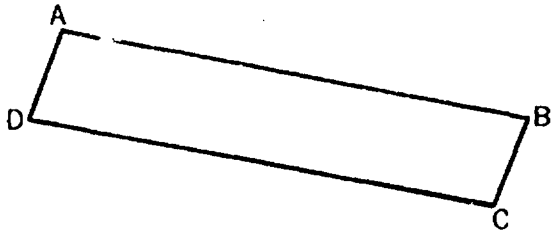
What else did you notice about the sides? ____________________

____

Is $\overline{AB}$ parallel to $\overline{DC}$? ____________________

Is $\overline{AD}$ parallel to $\overline{BC}$? ____________________

23. And here is another figure.



Write the lengths of the sides here.

$\overline{AB}$ is __________ inches long.

$\overline{CD}$ is __________ inches long.

$\overline{AD}$ is __________ inches long.

$\overline{BC}$ is __________ inches long.

Use your ruler and say what you notice about sides AB and DC and sides AD and BC besides the length.

____

____

24. In the last six examples, four were alike and two were different. What are the question numbers of the four which are alike?

____

18, 20, 22, 23

25. Remember what we said at the beginning of the lesson about describing figures by saying something about the sides. Say how you think that the four figures you named in the last question were alike.

____

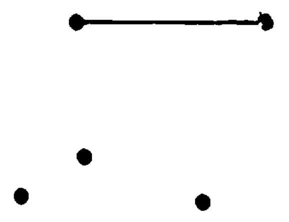
____

____

____

Two pairs of opposite sides were equal in length and two pair of opposite sides were parallel. Quadrilaterals which have two pairs of opposite sides equal in length and <u>two pair of opposite sides parallel</u> are called <u>parallelograms</u>.

26. Using a ruler, connect as many points as you need to finish the figure to make a quadrilateral that is <u>not</u> a parallelogram.



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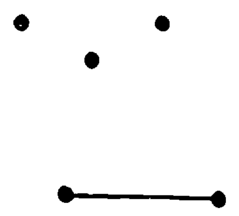
27. Using a ruler, connect as many points as you need to finish the figure so it is a parallelogram.



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28. All parallelograms have something special that not all quadrilaterals have. Parallelograms have ________ pair(s) of ___________ sides.

____

____

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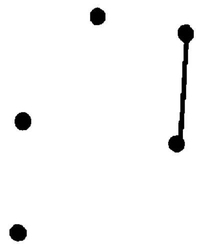
29. List all that is needed to completely describe parallelogram.

30. Using a ruler, connect as many points as needed to close the figure so it has 2 pairs of parallel sides.



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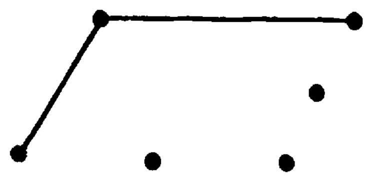
31. Using a ruler, complete this figure so that it is a quadrilateral but not a parallelogram.



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32. Using your ruler complete this figure so that it is a parallelogram.